PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXLIII.

PART I.

LONDON:

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MDCCCXLIII.

ADVERTISEMENT.

The Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions,* take this opportunity to acquaint the Public, that it fully appears, as well from the Council-books and Journals of the Society, as from repeated declarations which have been made in several former *Transactions,* that the printing of them was always, from time to time, the single act of the respective Secretaries till the Forty-seventh Volume; the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March 1752. And the grounds of their choice are, and will continue to be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgement of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body,

upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

A List of Public Institutions and Individuals, entitled to receive a copy of the Philosophical Transactions of each year, on making application for the same directly or through their respective agents, within five years of the date of publication.

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The University of Edinburgh.
The University of Glasgow.
The Observatory at Oxford.
The Observatory at Cambridge.
The Observatory at Dublin.
The Observatory at Armagh.
The Observatory at the Cape of Good Hope.
The Observatory at Paramatta.
The Observatory at Madras.
The Royal Institution of Great Britain.
The Royal Society, Edinburgh.
The Observatory, Trevandrum, East Indies.
The Astronomical Institution, Edinburgh.
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The Lowndes's Professor of Astronomy, Cambridge.
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The Royal Academy of Sciences at Paris.
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ROYAL MEDALS.

HER MAJESTY QUEEN VICTORIA, in restoring the Foundation of the Royal Medals, has been graciously pleased to approve of the following regulations for the award of them:

That the Royal Medals be given for such papers only as have been presented to the Royal Society, and inserted in their Transactions.

That the triennial Cycle of subjects be the same as that hitherto in operation: viz.

1. Astronomy; Physiology, including the Natural History of Organized Beings.
2. Physics; Geology or Mineralogy.
3. Mathematics; Chemistry.

That, in case no paper, coming within these stipulations, should be considered deserving of the Royal Medal, in any given year, the Council have the power of awarding such Medal to the author of any other paper on either of the several subjects forming the Cycle, that may have been presented to the Society and inserted in their Transactions; preference being given to the subjects of the year immediately preceding: the award being, in such case, subject to the approbation of Her Majesty.

The Council propose to give one of the Royal Medals in the year 1843 for the most important unpublished paper in Physics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1840, and prior to the termination of the Session in June 1843.

The Council propose also to give one of the Royal Medals in the year 1843 for the most important unpublished paper in Geology or Mineralogy, communicated to

the Royal Society for insertion in their Transactions after the termination of the Session in June 1840, and prior to the termination of the Session in June 1843.

The Council propose to give one of the Royal Medals in the year 1844 for the most important unpublished paper in Mathematics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1841, and prior to the termination of the Session in June 1844.

The Council propose also to give one of the Royal Medals in the year 1844 for the most important unpublished paper in Chemistry, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1841, and prior to the termination of the Session in June 1844.

The Council propose to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Astronomy, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

The Council propose also to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Physiology, including the Natural History of Organized Beings, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

The Council propose to give one of the Royal Medals in the year 1846 for the most important unpublished paper in Physics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1843, and prior to the termination of the Session in June 1846.

The Council propose also to give one of the Royal Medals in the year 1846 for the most important unpublished paper in Geology or Mineralogy, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1843, and prior to the termination of the Session in June 1846.

CONTENTS.

Adjudication of the Medals of the Royal Society for the year 1843 by the President and Council.

The Copley Medal to M. Jean Baptiste Dumas, for his late valuable researches in Organic Chemistry, particularly those contained in a series of memoirs on Chemical Types and the Doctrine of Substitution, and also for his elaborate investigations of the Atomic Weights of Carbon, Oxygen, Hydrogen, Nitrogen, and other elements.

The Royal Medal, in the department of Physics, to Professor James David Forbes, F.R.S., for his Paper entitled "On the Transparency of the Atmosphere, and the Law of Extinction of the Solar Rays in passing through it," published in the Philosophical Transactions for 1842.

The other Royal Medal, not having been awarded in the department of Mineralogy and Geology, was awarded in that of Physics to Professor Charles Wheatstone, F.R.S., for his Paper entitled, "An Account of several new Instruments and Processes for determining the Constants of a Voltaic Circuit," published in the Philosophical Transactions for 1843.

CONTENTS.

Errata in No. V. of the Contributions to Terrestrial Magnetism, Art. X.

Page 148, line 2 (Equation 4),

$$for\ \frac{\phi'}{A'\,\phi'}\cos\theta'\ read\ \frac{\phi'}{A'\,\phi}\cos\theta'.$$

Page 148, line 10 (Equation 11),

$$for\ \sqrt{(\cos\zeta + a\tan\theta)^2 + b^2\sin^2\zeta\tan\theta'}\ read\ \sqrt{(\cos\zeta + a\tan\theta)^2 + b^2\sin^2\zeta}\,.\tan\theta'.$$

Page 149, line 14 (Equation 16),

$$for\ \frac{H_w + H_e}{2\sqrt{H_w\,H_s}}\ read\ \frac{H_w + H_e}{2\sqrt{H_n\cdot H_s}}.$$

PHILOSOPHICAL TRANSACTIONS.

I. *On certain improvements on Photographic Processes described in a former Communication, and on the Parathermic Rays of the Solar Spectrum. By Sir* J. F. W. HERSCHEL, *Bart., K.H., F.R.S., &c.; in a Letter addressed to* S. HUNTER CHRISTIE *Esq., Sec. R.S. Communicated by* S. HUNTER CHRISTIE.

Received November 17,—Read November 17, 1842.

DEAR SIR,

231. I BEG leave herewith to submit for your inspection and that of the Royal Society, a series of photographic impressions illustrative of the chrysotype, cyanotype, and other processes, an account of which is given in the Postscript to my last paper on that subject, which has, by permission of the President and Council, been appended to the original in its printed form subsequently to the termination of the Session. In the interval which has since elapsed, besides the discovery of other photographic novelties (which may form the subject of future communications), I have been enabled materially to improve some of the processes there described; and these improvements, with a few remarks on some other points treated of in that paper, in relation to the processes in which the thermic rays are concerned, are now subjoined.

232. The positive cyanotype process described in Arts. 219, 220 of my papers, though beautiful in its effect (especially during the first few minutes of the appearance of the picture), is very precarious in its ultimate success, owing to causes there detailed. The remedies proposed are also only occasionally and partially successful, and in consequence this process, though exceedingly *easy* in its manipulations, could not be recommended as practically useful. After trying a vast variety of means to overcome these obstacles to its success, I have succeeded at last, by the simple addition of corrosive sublimate to the ammonio-citrate of iron with which the paper is prepared. The improved process, therefore, may be thus stated. Mix together equal measures of a saturated cold solution of corrosive sublimate, and a solution of am-

monio-citrate of iron, one part by weight of the salt to eleven parts water. No immediate precipitation takes place, and before any has time to do so, the mixture must be washed over paper (which should have rather a yellowish than a bluish cast), and dried. It is now ready for use, and I do not find that it is impaired by keeping. To use it, it must be exposed to the light till a faint, but yet perfectly visible picture is imprèssed, and till the border (if it be an engraving which is copied) has assumed a pale brown colour. Being withdrawn it is to be brushed over as rapidly as possible with a broad flat brush, dipped in a saturated solution of prussiate (ferrocyanate) of potash diluted with three times its bulk of gum-water, so strong as just to flow freely without adhesion to the lip of the vessel. All the care that is required is, that the film of liquid be very thinly, evenly, and above all, quickly spread. Being then allowed to dry in the dark, it rarely fails to produce a good picture. And what is very remarkable, it is *ipso facto* fixed as soon as dry, so at least as not to be injured by exposure to common day-light, immediately; and after a few days' keeping it becomes entirely so, and will bear strong lights uninjured. By long keeping, details at first barely seen come out, and the whole picture acquires a continually-increasing intensity, without however sacrificing distinctness; and by the same gradations its colour passes from purple to greenish-blue. Some experience, to be acquired only by practice, is necessary to determine the proper moment for withdrawing the photograph from the action of the light. If it be over-sunned, only the darker shades appear; if too little, the whole, though beautifully perfect in the first moments of its appearance, speedily runs into an indistinguishable blot.

233. The principal obstacle in the way of the employment of gold and silver as photographic ingredients for the production of negative models, to be used for retransfers, so as to multiply positive copies, arises from the want of absolute opacity in these metals or their oxides when in a state of minute division. The same objection does not apply, or applies with much less force, to mercury, which (probably owing to its fluid state, which prevents its particles from acquiring that excessive tenuity which a laminated form would admit, by reason of their capillary forces contracting each separately deposited particle into a sphere) is one of the most opake substances (after carbon) known. I find that this high degree of blackness and opacity may be induced on a mercurial photograph prepared as in Art. 228, by a process which is in itself not a little curious and instructive, as affording a kind of parallel to the stimulating action of Mr. Talbot's second application of nitrate of silver, in his beautiful kalotype process. The nature of the process in question will be best illustrated by describing the experiment which led to it.

234. It frequently happens that papers prepared with nitrate of mercury and the ammonio-citrates or tartrates, with or without addition of tartaric or citric acid, fail to exhibit the peculiar properties described in Arts. 228, 229 at all satisfactorily. Indeed, to bring on the peculiar velvety effect there described, a high degree of intensity of sunshine seems to be an essential requisite, as, in a feeble sun, I have never

obtained even an approach to it. A paper prepared (Oct. 28, 1842) according to the instructions of Art. 229 in every respect, except in the proportion of tartaric acid (which was somewhat less than that recommended), proved very little sensitive. A strip of this paper, half shaded, acquired after a few minutes' exposure to sunshine only a feeble brown colour over the sunned portion. Being then withdrawn, it was washed over with nitrate of mercury. *Immediately* the sunned portion began to darken very rapidly while the shaded part was unaffected, and ultimately assumed a deep brown hue. Exposed while yet wet to the sunshine, this passed rapidly to intense blackness, while the portion originally shaded, which had undergone the same subsequent application, and which was now equally exposed to the sun, sustained in the short time required for bringing on this effect, no appreciable change. Indeed it seemed rather to have become more insensible than before.

235. Not alone nitrate of mercury is capable of thus exciting or stimulating the dormant photographic impression on such paper. To my very great surprise, I found the same effect to be produced by *water* sparingly applied, so as only to moisten the paper. Across the sunned and shaded portions of a strip of the mercurialized paper, exposed till a pale brown was developed in the former portion, were drawn two streaks, one of weak nitrate of mercury and one of spring water. Both, after a very short interval, passed to an intense brown on the sunned half, the shaded remaining unchanged. Edging the streak produced by the nitrate was a black border, that produced by the water was uniform. The *whole* paper was now exposed for a short time to the sun, which rapidly converted to intense blackness both the streaks on the previously sunned half, while it produced no perceptible change in the other. I found this experiment to succeed on many different varieties of paper, and with very considerable latitude in the dosage of the ingredients. It was most successful in the case of a paper prepared with a cream, formed by mixing one measure ammonio-*tartrate* of iron (strength $\frac{1}{12}$*) and two saturated protonitrate of mercury, leaving out the free tartaric acid altogether, which, among many other doses of these two ingredients, proved also, generally, the most sensitive to light.

236. Led by these indications I prepared a paper by washing, first with a weak solution of ammonio-citrate of iron (strength $\frac{1}{20}$), and when dry, with saturated protonitrate of mercury. It was exposed *when barely dry enough, not to feel damp,* with an engraving in a frame to a hazy and declining sun. In about twenty minutes a very pale and feeble photograph was produced. Excited as above, by water, it gained but little in intensity (for it deserves remark that the *increase* of apparent intensity produced by either water or the nitrate, is in direct *proportion* to the force of the original impression, which, as observed, was in this case very faint). It was then held for about five minutes in the sun (near setting), and by degrees, and with the utmost regularity of gradation over every part of the picture, each line assumed an

* By this I understand one part (by weight) salt + 11 water.

inky blackness, the lights and shades being exquisitely preserved in their due proportions, and the ground being hardly perceptibly discoloured. The result was a very beautiful and perfect negative photograph.

237. This singular power of water to excite the dormant impression, strongly recalls the analogous power of moisture to deepen the tints photographically impressed on auriferous papers, of which an instance is given in Art. 45, and of which a still more striking example is shown as follows. Let a paper be washed first with ammonio-citrate of iron, and when dry with neutralized chloride of gold, and thoroughly dried in the dark. It is then, apparently, almost insensible to light; a slip of it half exposed to sun being hardly impressed in any perceptible degree in many minutes; yet if breathed on, the impression comes out very strong and full, deepening by degrees to an extraordinary strength. Treated in the same manner, silver also exhibits a similar property*. Nor, indeed, is there any feature in photography more general or more remarkable than the influence exercised by the presence of a certain degree of moisture in favouring the action of light, whether direct or indirect.

238. There is this difference, however, in the excitement produced by simple water and by the mercurial solution, viz. that the latter is permanent, the former liable to fade; at least I have found this to be the case with the brown tinge produced by it in shade, though when blackened by a second exposure to sun no difference is perceived. On the other hand, when the nitrate is used, the brown hue frequently passes to absolute blackness without any subsequent exposure to sunshine; and in that case the photographs produced have an intensity and opacity scarcely, if at all, inferior to that of printing ink.

239. This high degree of opacity and depth, together with the comparative insensibility of the ground, is evidently capable of being most usefully applied to the production of retransfers. In fact, the photographs so produced being negative are so far fitted for the purpose, and if used as models while in this, their transition state, and as it were self-fixed, so far from being injured by the transmission of light, they are actually acquiring additional sharpness and depth by every beam which passes. By *seizing therefore the right point of dryness*, and by using a very sensitive paper to receive the impression, there is no reason to doubt of success in procuring very perfect positive transfers. Some trials I have made have satisfied me as to the practi-

* Note added Dec. 21.—The excitement is produced on such paper by the ordinary moisture of the atmosphere, and goes on slowly working its effect in the dark, apparently without *other* limit than is afforded by the supply of ingredients present. In the case of silver, it ultimately produced a perfect *silvering* of all the sunned portions. Very singular and beautiful photographs having much resemblance to Daguerreotype pictures, are thus produced; the negative character changing by keeping, and by quite insensible gradations, to positive; and the shades exhibiting a most singular *chatoyant* change of colour from ruddy-brown to black when held more or less obliquely. No doubt also gold pictures with the metallic lustre might be obtained by the same process, though I have not tried the experiment.—J. F. W. H.

cability of this, however contrary it may at first sight appear to the usual conditions of photography.

240. In the positive cyanotype process, as improved by the addition of corrosive sublimate above recommended, we are furnished with another instance of a transformation effected by heat, analogous to those described in Art. 223. A picture prepared by this process, if heated, is transformed from positive to negative and from blue to brown. On keeping the blue colour is restored, *as well as the positive character*. In Art. 224 I have referred this curious action to certain rays, which, whether they be regarded as rays of heat, or light, or of some influence, *sui generis*, accompany in the spectrum the red and orange rays, and are also copiously emitted by heated bodies short of redness. These rays are distinguished from those of light by being invisible; they are also distinguished from the purely calorific rays beyond the spectrum by their possessing the properties recorded in Arts. 160, 223, either exclusively of the calorific rays, or in a very much higher degree. They may perhaps not improperly be regarded as bearing the same relation to the calorific spectrum which the photographic rays do to the luminous one, and if the restriction to these rays of the term *thermic* as distinct from *calorific* be not (as I think in fact it is not) a sufficient distinction, I would propose the term *parathermic rays* to designate them. These are the rays (if I may indulge in speculation which I propose to bring to the test of experiment hereafter) which I conceive to be active in producing those singular molecular affections which determine the precipitation of vapours in the experiments of Messrs. Draper, Moser, and Hunt, and which will probably lead to important discoveries as to the intimate nature of those forces resident on the surfaces of bodies to which M. Dutrochet has given the name of epipolic forces. These also, I cannot help considering it as highly probable, are the rays which radiated from molecule to molecule in the interior of bodies, determine the discharge of vegetable colours at the boiling temperature (see Art. 162), and the innumerable isomeric and other atomic transformations of organic bodies which take place at temperatures below redness. The term latent light, I confess, carries with it to my mind no distinct conception; still less capable of being introduced into scientific language appears such a term as *invisible* light. Whether the rays to which such terms have been applied shall or shall not turn out, on inquiry, to be identical with my "parathermic" rays, can only be decided by experiments to be instituted for that purpose; but at all events I feel strongly disposed to insist on the distinction between *these* rays and those of *pure heat*, and in referring them to a peculiar region of the spectrum (though without denying their more sparing distribution over every other part of it), I consider them at all events as sufficiently identified by their characters, there eminently developed, to become legitimate objects of scientific discussion.

241. The action of the calorific rays, *as such*, demonstrated by the rapidity of evaporation of water or alcohol which takes place under their influence, is traced (in addition to the facts brought forward in the notes on my first paper on this subject)

in the experiments described in Arts. 205, 208, in the latter of which a chemical action, distinct from the calorific, seems also traceable. I may here also mention that the rays which operate the change of colour in muriate of cobalt from rose colour to green appear to be the calorific rays generally, and the effect to be one of simple evaporation; since under the action of the spectrum I find the green colour not restricted to the "parathermic" region, but to extend far beyond the red, and to be, in fact, commensurate with the calorific spectrum, so far as it could be traced in an experiment made under unfavourable circumstances.

I have the honour to remain, my dear Sir,

Yours very truly,

J. F. W. Herschel.

Collingwood, Nov. 15, 1842.

II. *Researches on the Decomposition and Disintegration of Phosphatic Vesical Calculi, and on the Introduction of Chemical Decomponents into the Living Bladder.* By S. Elliott Hoskins, *M.D.* *Communicated by* P. M. Roget, *M.D.*, *Sec. R.S.*

Received December 8, 1842,—Read February 23, 1843.

In the following account of my humble investigations, I shall confine myself, as much as possible, to the physical phænomena which have fallen under my observation; reserving those of a physiological or pathological character for a sphere more exclusively professional.

Although Fourcroy strongly expressed it as his opinion, that calculi would, sooner or later, be dissolved by the introduction of chemical agents into the living bladder; and, although some eminent writers of the present day are of the same opinion; there are others, no less eminent, who entertain doubts as to the adaptation of any direct chemical means to so desirable an end.

I must here state, that my reason for clinging to the creed of the former rather than to that of the latter, was founded on the increasing list of new agents, which chemistry is daily placing at the disposal of the experimenter. Amongst these I hoped to discover some agent which should be more energetic in its action on calculi, and less obnoxious to the living tissues, than any hitherto proposed.

For several months my efforts were confined to attempts at dissolving uric acid and the urates, knowing that they constitute a predominating variety among calculous concretions: and, although I met with sufficient success to encourage perseverance, reasons not necessary to mention, induced me to abandon these experiments, and to prosecute others on phosphatic calculi. The results of the latter it is now my purpose to detail.

A series of experiments was undertaken with the whole range of acids, vegetable as well as mineral, combined in various ways and in various proportions. There could be no doubt as to the solvent power even of the weakest; but their irritating effect on the tongue, and on the conjunctival membrane, was equally obvious. Not one among them was found calculated to fulfil the two indications I required; a circumstance which tends to corroborate, in a great degree, Dr. Prout's statement,—"that uncombined agents of the alkaline or acid kind are ill-calculated to act as solvents for calculi; and that solvents are to be sought for among a class of harmless and unirritating compounds, the elements of which are so associated as to act at the same time with respect to calculous ingredients, both as alkalies and acids*."

* Prout on the Stomach and Urinary Diseases, p. 458.

"At present," continues Dr. Prout, "no such class of compounds of a decided character are known, or appear likely to be discovered; yet, as no chemical fact can be stated *à priori*, we know not what remains in store among the arcana of nature."

The conviction I had acquired of the truth of these observations induced me to abandon all attempts at positive or direct solution, but rather to try the effect of indirect means, namely those of *decomposition* and disintegration; as preliminaries to solution by some bland fluid, or to mechanical removal, by the injection of a continuous stream of liquid through a double current catheter.

It appeared, hitherto, to have been the object, to act on calculi by *single* elective affinity only; that is, to dissolve the base before it was disengaged from its associated acid. This mode having failed to produce agents sufficiently active on the one hand, and mild on the other; it seemed more in accordance with chemical principles, and more likely to effect the desired end, if *complex* affinity could be brought into play.

It frequently happens, that reactions occur under the influence of double decomposition, which are not produced by simple affinity: thus, ammonia alone will not decompose nitrate of lime, though carbonate of ammonia answers the purpose readily. The triteness of this example will, I trust, be excused in favour of the aptitude with which it illustrates my meaning.

For the above purpose an agent is required, the base of which shall be so attractive of the acid of the calculus, as to withdraw it from its allegiance; whilst the acid of the agent unites with the basic ingredients of the calculus, to form with them salts of easy solution.

This view of the subject seems to reveal a class of agents so mild as to come directly under Dr. Prout's category. During their employment, the combined acids are set free *only* in combining proportions, to be neutralized in their nascent state by the proper base, and *removed out of the sphere of action before they have time, as it were, to act upon the animal tissues.* Whereas, free acids of sufficient strength to act on the concretion, and in sufficient quantity, cannot be prevented from irritating, in a greater or less degree, the animal membranes with which they happen to be in contact.

The facility with which salts of lead decompose the phosphates, a facility which has led to their employment as tests of the presence of phosphoric acid, pointed them out as agents well-fitted for the present purpose.

Fragments of phosphatic calculi were accordingly immersed in solutions of neutral acetate of lead, of various degrees of concentration, and at different temperatures, but without result; even when the assay, reduced to powder, was placed in these fluids and viewed with the microscope, no chemical action, however slight, was discernible. I was disappointed, but nevertheless induced to try some other combination of the metal.

Dr. Prout mentions, in his valuable work before cited, that fluids containing malic acid possess peculiar powers in arresting the deposition of the phosphates. The same gentleman informed me that the solvent powers of the *Alchemilla arvensis* reside in the malic acid which this plant contains, My own experience has unequivocally

proved to me the efficacy of cider, as an ordinary drink, in cases of phosphatic urinary deposit accompanying rickets, and diseases of the lumbar vertebræ.

From these circumstances I was inclined to believe, that although the acetate had failed, a malate or super-malate of lead would be likely to act as a decomponent of phosphatic concretions. Another reason for selecting malic acid was the solubility of the salts it forms with the bases of these calculi, viz. magnesia, lime, &c. Having no readier means of procuring the malate, I sought to prepare it from cider vinegar, or what is called *cidre-aigre* in contra-distinction to *vin-aigre*, a liquid commonly used as a substitute for wine or malt-vinegar, in the farm-houses and cottages of the Channel Islands.

To this *cidre-aigre* a watery solution of neutral acetate of lead was added, till precipitation no longer took place. The liquid, on being filtered, was clear, devoid of acidity or acrimony; and, as Dr. Christison states, with respect to acescent wines to which lead has been added, it possessed "a very pleasant sweetness, quite unmingled with metallic astringency*."

The whole of the passage, relating to French wines, from which the above sentence is quoted, seems particularly applicable to the liquid under consideration. In default, however, of any authentic analysis of cider-vinegar, my observations induced me to believe, that the acids it contained were the acetic, malic, and tartaric; but as I was unwilling to interrupt the course of experiments, in order to analyse it, I am unable to determine this point with the necessary accuracy.

Nevertheless, whatever may be its composition, the immersion of fragments of phosphatic calculi in the liquid formed as before stated, was followed by very striking results: rapid chemical action ensued, visible to the naked eye; when viewed by means of a low microscopic power, vehement decomposing action was manifest, the calculous particles becoming surrounded by *areolæ* or *nebulæ* of white sediment, which continued increasing until each fragment was reduced to a pulpy state resembling mortar, perfectly soluble in very dilute nitric acid.

On suspending a fragment of fusible calculus, by means of horse-hair, in a test-glass containing the fluid, it became at once involved in a white cloud, from which a continuous stream of precipitate gravitated to the bottom of the glass. After the lapse of half an hour the calculus was found to have lost weight. This was an important fact, without which it might have been supposed that decomposition of the solution alone had given rise to the precipitate.

Being inclined to doubt the evidence of my senses, rather than arrive at a false conclusion, I repeated the experiment. Another particle of triple phosphate was placed in a fresh quantity of the liquid; at the moment of immersion chemical action commenced, and pursued the same course, until the fragment became a semi-solid mass, readily disintegrated. After a time nothing remained but the shreds of mucus, or other animal matter, which had cemented the earthy ingredients together.

The result of analogous experiments, performed subsequently, warrants me in sta-

* Christison on Poisons, p. 407.

ting that the precipitate in the present instance was chiefly phosphate of lead*; it may likewise be fairly inferred, that the other ingredients composing the calculus had formed soluble salts with the malic and acetic acids of the decomponent. For it was manifest that the acids contained in *cidre-aigre* had formed soluble salts with oxide of lead, and that these salts, even when dissolved in such a quantity of fluid as to possess scarcely any taste and no pungency, were capable of decomposing phosphatic calculi. The liquid in this state, however, was objectionable, in a practical as well as a scientific point of view, on account of its colour, odour, and indeterminate strength. It therefore became desirable to attempt the formation of some definite salt, of analogous composition, which, by solution in water, should form a decomposing agent, of a strength which might at all times be depended on; capable also of being varied aecording to circumstances.

In theory, the nearest approach to an agent of this kind seemed to be a super malate of lead; for, although the neutral malate was known to be insoluble in water, it was deemed possible that, by some modification, its solubility might be increased. This I found to be the case.

Crystals of malate of lead, in fine powder, were diffused in water, and thoroughly decomposed by sulphuretted hydrogen, so as to leave malic acid in solution; this was filtered and boiled to expel the gas. While still hot, fresh crystals of malate of lead were added to the fluid, which was then allowed to cool, and again filtered. On suspending specimens of phosphatic calculi in this liquid (which, though sensibly acid when tested, was perfectly insipid), chemical action took place, but by no means rapidly. This was, nevertheless, one step towards the acquirement of a definite compound.

Recurring to my former conjectures as to the nature of the salts held in solution by the filtered *aigre*, pure crystals of malate of lead were gradually added to warm dilute acetic acid†. This mixture was heated gently for some time, and afforded a better decomponent than the former, but still not so active as the original cider-vinegar compound.

After a long series of experiments to the same effect, which it is unnecessary to detail, I arrived at the following conclusions:—1st, that malic acid, unless concentrated, exerts but little solvent action on phosphatic calculi; 2nd, that a weak solution of super-malate of lead *does* act as a decomponent; 3rd, that a solution of aceto-malate, if I may be allowed so to call the liquid last described, is tolerably active; but finally, that none of the preparations of malic acid, already alluded to, are so active as the cider-vinegar solution.

The close resemblance said to exist between genuine malic acid, procured from the *Sorbus aucuparia*, and the factitious, prepared by the action of dilute nitric acid on sugar, induced me to turn my attention to what, by some chemists, is called saccharie, by others oxal-hydric acid. By slightly varying BERZELIUS's process‡, so as to avoid the diseoloration produced, as he says, by humic acid, a very pure saccharate

* See p. 280.

† Five parts of pure acid to 480 of distilled water.

‡ This modification consists in heating the mixture of dilute acid and sugar, until the evolution of red fumes

of lead was prepared. From this, saccharic acid and super-saccharate of lead were obtained by the aid of sulphuretted hydrogen, as described when speaking of the malates of lead. Saccharic acid, however, unless concentrated, exerted no greater influence on phosphatic concretions than malic acid; the neutral saccharate of lead was likewise inert, whereas the supersalt proved so active, and yet so mild, that it seemed better calculated than any agent hitherto tried, to fulfil the prescribed conditions. But as the sulphuretted hydrogen process was tedious and unpleasant, Thenard's statement as to the solubility of the malate in acetic acid was applied to the saccharate of lead: a preparation of this kind seemed the more likely to answer from its similarity to the *cidre-aigre* solution.

An *aceto-saccharate* was, in the first instance, formed according to Berzelius's directions*; but as this process was likewise somewhat elaborate, I endeavoured to abbreviate it as follows:—Five parts of saccharate of lead, and the same number of minims of strong acetic acid, were added to a fluid ounce of distilled water, which was gently heated for a short time; a small quantity of the lead salt was thereby dissolved, not more than half a grain. This solution, although perfectly tasteless, acted speedily and with energy on any phosphatic fragment of calculus suspended in it. The solution on the most careful evaporation yielded no crystals, but was converted by heat into a viscous syrup, which ultimately became a species of *caramel.* The liquid, therefore, although available for experimental, was not sufficiently definite for practical purposes. But as Liebig mentions no less than three definite compounds of oxide of lead with saccharic acid, I did not despair of succeeding in the formation of a salt, such, in all respects, as I required. "L'acide saccharique," says Liebig, "est très rémarquable par le grand nombre de combinaisons qu'il forme avec les bases."

It now became my object to form an *acid* saccharate of lead, which was accomplished thus:—a portion of pulverized saccharate of lead was dissolved in a sufficient quantity of cold dilute nitric acid†. The solution, after being filtered, and gradually evaporated, yielded a quantity of perfectly transparent, amber-coloured crystals, in the form of regular hexagonal plates or prisms. I have reason to believe that the colour is essential to the salt, for when I endeavonred to purify it by re-solution in dilute nitric acid, although it still formed hexagonal crystals, the salt had lost its activity as a decomponent.

One grain of this salt, which I shall call nitro-saccharate of lead, moistened with

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commences, and then instantly removing the spirit-lamp. The fumes continue to be disengaged for some time, and when they have entirely ceased, decomposition by lime, and precipitation by acetate of lead may ensue.

* "Quand on chauffe," says he, "un mélange d'acide acétique et de saccharate calcique dissous, et qu'on ajoute à ce mélange de l'acétate d'oxyde de plomb jusqu' à ce que le précipité commence à ne plus se rédissoudre, le sel écailleux cristallise en plus grande quantité par le refroidissement." These crystalline scales, moistened with acetic acid, and dissolved in water, form a good decomponent.

† One acid to nineteen water.

five drops of pure saccharic acid, and dissolved in a fluid ounce of distilled water, formed a bland liquid without any astringency, although it possessed slight acid reaction. It acted with rapidity on various specimens of phosphatic calculi, forming around each, at the moment of immersion, the dense nebula formerly described, from which a white precipitate subsided. Chemically speaking, this was the most active agent yet experimented with, whilst its sensible character was so mild as to be tolerated with perfect impunity by the urethral and conjunctival membranes.

The following experiments, selected from a great number of others, to the same effect, will suffice to show the results of the action of this nitro-saccharate solution on human phosphatic calculi.

Experiment I.—Seven fragments of various sizes and figures, taken indiscriminately from a collection of phosphatic specimens, were placed in distilled water until air-bubbles ceased to be disengaged from them: they were found to weigh collectively, after being allowed to drain for a minute or two on bibulous paper, one hundred grains.

These fragments, each suspended by a horse-hair, were placed in ten fluid ounces of the above-mentioned nitro-saccharate solution for twenty-five minutes, during which time the temperature of the fluid was maintained at 98° Fahr. They were then removed and plunged into ten ounces of fresh solution, of the same strength and temperature, for a quarter of an hour. In both cases, copious precipitation took place from each fragment, and accumulated at the bottom of the glasses. The calculi were then removed, drained for a few minutes on filtering paper, and, on being re-weighed, were found to have lost twelve grains*.

The two portions of solution, together amounting to twenty ounces, were then passed through a filter; and the precipitate, after being washed and carefully dried, was found to weigh *eleven* grains. A small quantity of it, heated alone on charcoal by means of the blowpipe, gave indications of the presence of phosphate of lead. In order, however, to determine the nature of the acid contained in the lead precipitate, another portion of it was dissolved in dilute nitric acid; to this solution was added a drop or two of nitrate of silver, and on being cautiously neutralized by weak liquid ammonia, a yellow precipitate, characteristic of the presence of phosphate of silver, made its appearance†.

A third portion of the dried precipitate was mixed with borax, and fused by the blowpipe on charcoal; the bead thus formed was transfixed by a fine needle, and strongly heated in the interior flame; on being broken after cooling, it was found to

* The greater the extent of surface, the greater, generally speaking, will be the amount of decomposition, so that agents of this kind will, I trust, come with great effect to the aid of *lithotrity*.

† I may perhaps be permitted to remark, that in order to render this test determinate, the following precaution is necessary. If the assay be dissolved in *dilute* nitric acid, *weak* liquid ammonia must be used for neutralization, otherwise no yellow precipitate will be formed. On the other hand, if *strong* nitric acid is used for solution, it must be neutralized by strong liquid ammonia. In both cases the ammonia must be added cautiously, for an excess, however small, destroys the yellow colour of the precipitate.

consist of magnetic particles of phosphuret of iron, affording another proof of the presence of phosphoric acid in the precipitate.

With respect to the filtered solution, half of it, amounting to ten ounces, on being cautiously evaporated to dryness, yielded rather more than nine grains of solid residue, which, however, was not analysed. The remaining ten ounces were treated with sulphuretted hydrogen, so as to decompose the *whole* of the salt of lead: it was then filtered, boiled, and tested with oxalate of ammonia, which produced after a time a trifling precipitation of lime: the superaddition of liquid ammonia gave no evidence of the presence of magnesia.

At the commencement of the experiment the solid materials amounted to 120 grains, viz.—

Seven calculous fragments	=	100 grs.
Nitro-saccharate of lead in solution	=	20
		120

After the operation the following seems to have been the arrangement of the ingredients:—

Calculous fragments after immersion for forty minutes . . .	=	88 grs.
Precipitate separated by filtration and dried	=	11
Residue of filtered fluid after evaporation	=	19
Unaccounted for	=	2
		120

Supposing the precipitate from the calculi to have consisted entirely of phosphate of lead, the equivalent of acid would, on a rough calculation, have been 2·4; so that, had the assay been inorganic, or definite in composition, the exact amount of decomposed salt might have been estimated. Under existing circumstances rude approximations are sufficient; but I hope to be enabled to illustrate this part of the subject at some future period, by more careful and extended analyses.

The *second experiment* was conducted by suspending a fragment of fusible calculus, weighing thirty grains, in five ounces of the nitro-saccharate solution for half an hour. At the expiration of this period the fragment had lost eight grains, and the precipitate arising from its decomposition, when carefully dried, weighed rather more. The filtered fluid, treated as in the former experiment, contained a small quantity of lime.

In the course of the present experiment some very curious and interesting phænomena were observed. A copious, dense, white sediment, descended as usual in a stream from the calculus; but, besides this, an ascending current was remarked: it consisted of air bubbles, bearing with them a white stream, similar to, though smaller than that which was seen descending; on arriving at the surface the bubbles escaped, and the white particles they had rendered buoyant, subsided steadily, like sparks from an exploded rocket. This circulation, similar to the ascending and descending

currents produced in liquids by heat, continued until decomposition from saturation of the solution, or other causes had ceased.

The same fragment was afterwards immersed in other solutions of a similar kind, with a view of ascertaining its rate of decomposition:—but after decomposition had been going on steadily for some time, precipitation *suddenly* ceased. Under the idea that precipitation had ceased in consequence of the solution having become saturated, fresh quantities were tried, but without any renewal of chemical action; although other phosphatic fragments plunged into the same fluid were readily acted on. The cause of cessation, therefore, could only be attributed to some change in the character of the assay; on examination, instead of being white, friable, and homogeneous in texture, it had become fawn-coloured, dense, and striated; and yielded unequivocally, uric acid reaction. This accounted for the abrupt cessation of chemical action, and bore testimony to the effects of the saturnine solution on the phosphatic ingredients; for it was evident that the latter had constituted the outer coating of an uric acid nucleus in the fragment under examination.

The result of experiments with other salts of lead, as well as with those of mercury, baryta, and others, confirm the facts already stated; viz. that almost all supersalts of lead, especially with vegetable acids, act as ready decomponents of the calculi under consideration. Even the acetate, which in its neutral state is inert, becomes active by the superaddition of a minute quantity of its own proper acid: and, in like manner, the addition of a few drops of lactic*, malic, racemic, or formic acids to solutions of their neutral salts, produces a class of active decomposing agents, so effectual, that either of them may be considered to afford secure means for discriminating the phosphatic from other varieties of calculi.

An interesting and perchance important circumstance connected with this part of the subject, relates to the *strength* of the solution, which appears to be in *inverse ratio* to its decomposing power. Thus, a saturated solution of acetate of lead, acidulated pretty strongly with acetic acid, is inactive; whereas, one grain of the salt, with five drops of the acid, dissolved in one fluid ounce of tepid water, produces rapid and steady decomposition.

This fact has been carefully verified by repeated experiments; for instance, the moment a portion of calculus, which had been steadily decomposing in a weak solution, is plunged into a stronger, action abruptly ceases; it is as suddenly re-established when the assay is returned to the weaker solution. This alternation from weak to strong, and the reverse, was often repeated with solutions variously modified, but invariably with the same general result.

On first remarking the above circumstance, I was not aware that Berzelius had previously recorded a somewhat similar fact in relation to the action of weak solu-

* When a fragment of phosphatic calculus is placed in a solution of super-lactate of lead, under the microscope a dense areola at first surrounds it; from this, after a time, radii proceed, until the assay assumes a stellar appearance, of dazzling whiteness.

tions of borate of soda on uric acid; and that, on the authority of WETZLAR, he had stated that uric acid is soluble in *weak* solutions of *carbonate* of potash*.

The preceding experiments being apparently conclusive as to the decomposing effect of certain salts of lead on phosphatic calculi, out of the body; the next point to be determined was the effect likely to be produced by the introduction of their solutions into the living bladder. They had been found, on repeated trial, inoffensive to the eye and to the urethra; they are constantly applied to abraded and inflamed surfaces, as well as used internally, with the greatest advantage: and, although some of these salts, by long-continued absorption, are apt to produce a train of specific morbid symptoms, it has been stated by physicians of eminence, that lead acts deleteriously only when imbibed in the shape of a carbonate; that when the acetate appears to produce *colica pictonum*, it does so from being converted, after its reception into the body, into a carbonate; and furthermore, that this conversion may be avoided by super-acidulation, the salt may then be administered with perfect safety in large and efficient quantities. My observations tend to prove, that this super-acidulation is *essential* to the due action of the decomposing fluids I propose. Whatever salt of lead may be employed must be moistened with a small quantity of its own proper acid, or a few drops of pure acetic acid, PREVIOUS to the addition of water. In a chemical as well as therapeutical point of view this is essential:—1st, it secures the perfect solution of the salt and its consequent activity as a decomponent; 2nd, the super-addition of acid secures against the formation of any of the deleterious carbonate.

In order, however, that I might be perfectly satisfied as to the comparatively innocuous qualities of the before-named salts, I undertook a series of experiments with them on sheep; introducing the fluids into the bladder daily, for several weeks consecutively, and having the animals killed at different periods during the investigation. In none of the sheep experimented on, were untoward symptoms excited, either general or local.

It may be objected, that the membrane lining the viscera of graminivorous animals is less susceptible than that which performs the same office in man; but as, on trial, liquids which irritate and inflame the human organs, act in the same way, and with the same rapidity on those of the sheep, I see no reason to believe that the one is less susceptible of such impressions than the other. Experiments of a personal nature, not necessary to particularize, were also resorted to, and contributed to the conviction, that no evil could accrue from the continued introduction of saturnine solutions into the bladder†. The following cases not only prove this fact, but

* "Quand la liqueur ne contient qu'un demi pour cent de carbonate alcalin, l'acide urique s'y dissout assez rapidement." BERZELIUS, Traité de Chimie.

† I refrain, for obvious reasons, from entering into particulars as to the general effect of solutions of the salts of lead in various morbid states of the bladder; although I may be allowed perhaps to direct attention to the property these salts possess of coagulating mucus,—a property they do not fail to exercise on the secretion from the living organ, independently of their decomponent effects on the phosphate of lime which that secre-

furthermore that the solutions are freely tolerated by the organ, even when rendered morbidly irritable by the presence of the stone.

The first case to be mentioned is that of a gentleman, seventy years of age, who had long been suffering from vesical affection, accompanied by alkaline urine, phosphatic sediment, and the copious formation of ropy mucus. The catheter, when introduced, was felt to grate over calcareous concretions imbedded in the prostate gland.

In this case, a very dilute solution of nitric acid, one drop to the ounce of water, could only be retained a minute or two, its use being followed by considerable pain, which lasted for several hours; whereas the nitro-saccharate of lead solution, although retained for *fifty* minutes, produced no inconvenience, either at the time or subsequently. It was repeated daily, or every second day, for upwards of a month, and has been again resumed at the patient's request*.

The second case was one in which two calculi existed; the one was crushed successfully. The bladder was extremely irritable; nevertheless, the solution, injected at frequent intervals, for a fortnight or three weeks, produced no greater uneasiness at the time, or irritability afterwards, than an equal quantity of warm water. The fragments voided by this patient were found to consist of a mulberry nucleus with a coating of phosphatic material, readily acted upon by the solution.

The third case was also one of phosphatic calculus in an irritable bladder. The solution of nitro-saccharate was used daily for a week, and retained for half an hour at a time, not only without annoyance, but often with positive comfort. The gentleman, however, not having patience to await its action on the calculus, nothing further was ascertained.

It will be sufficiently evident, from these mere outlines, that the cases themselves were utterly unfavourable for testing the LITHONTRIPTIC powers of the solution: they are, nevertheless, well-fitted to afford evidence of its being neither irritating nor injurious, when introduced with proper restrictions into the bladder.

The establishment of the latter fact, although an important feature in the present communication, is not more so than the results which tend to denote the advantage of using DECOMPONENTS, rather than solvents. The latter view of the subject reveals a class of mild, but effectual, agents hitherto untried, and points out a principle, the application of which, I trust and anticipate, will lead to the discovery of similar agents for the *decomposition* of the other varieties of calculi which afflict the human race.

Guernsey, December 1, 1842.

tion often contains. Other matters connected with the mechanical means for introducing the fluid, the action of various decomponents contained in the urine, &c., must be reserved for consideration elsewhere.

* This gentleman is, I understand, much benefited. The instrument is no longer felt to grate over calcareous matter; and he voids the vesical contents more freely.

III. *Experimental Researches in Electricity.—Eighteenth Series.*

By Michael Faraday, *Esq., D.C.L. F.R.S., Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acadd. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, &c. &c.*

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§ 25. *On the electricity evolved by the friction of water and steam against other bodies.*

2075. Two years ago an experiment was described by Mr. Armstrong and others*, in which the issue of a stream of high pressure steam into the air produced abundance of electricity. The source of the electricity was not ascertained, but was supposed to be the evaporation or change of state of the water, and to have a direct relation to atmospheric electricity. I have at various times since May of last year been working upon the subject, and though I perceive Mr. Armstrong has, in recent communications, anticipated by publication some of the facts which I also have obtained, the Royal Society may still perhaps think a compressed account of my results and conclusions, which include many other important points, worthy its attention.

2076. The apparatus I have used was not competent to furnish me with much steam or a high pressure, but I found it sufficient for my purpose, which was the investigation of the effect and its cause, and not necessarily an increase of the electric development. Mr. Armstrong, as is shown by a recent paper, has well effected the latter†. The boiler I used, belonging to the London Institution, would hold about ten gallons of water, and allow the evaporation of five gallons. A pipe $4\frac{1}{2}$ feet long was attached to it, at the end of which was a large stop-cock and a metal globe, of the capacity of thirty-two cubic inches, which I will call the *steam-globe*, and to this globe, by its mouth-piece, could be attached various forms of apparatus, serving as vents for the issuing steam‡. Thus a cock could be connected with the steam-globe, and this cock be used as the experimental steam-passage; or a wooden tube could be screwed in; or a small metal or glass tube put through a good cork, and the cork screwed in; and in these cases the steam way of the globe and tube leading to the boiler was so large, that they might be considered as part of the boiler, and these terminal passages as the obstacles which, restraining the issue of steam, produced any important degree of friction.

* Philosophical Magazine, 1840, vol. xvii. pp. 370, 452, &c.

† Ibid. 1843, vol. xxii. p. 1.

‡ This globe and the pieces of apparatus are represented upon a scale of one-fourth in the Plate belonging to this paper.

2077. Another issue piece consisted of a metal tube terminated by a metal funnel, and of a cone advancing by a screw more or less into the funnel, so that the steam as it rushed forth beat against the cone (Plate I. fig. 2.); and this cone could either be electrically connected with the funnel and boiler, or be insulated.

2078. Another terminal piece consisted of a tube, with a stop-cock and feeder attached to the top part of it, by which any fluid could be admitted into the passage, and carried on with the steam (fig. 3.).

2079. In another terminal piece, a small cylindrical chamber was constructed (fig. 4.) into which different fluids could be introduced, so that, when the cocks were opened, the steam passing on from the steam-globe (2076.) should then enter this chamber and take up anything that was there, and so proceed with it into the final passage, or out against the cone (2077.), according as the apparatus had been combined together. This little chamber I will always call C.

2080. The pressure at which I worked with the steam was from eight to thirteen inches of mercury, never higher than thirteen inches, or about two-fifths of an atmosphere.

2081. The boiler was insulated on three small blocks of lac, the chimney being connected by a piece of funnel-pipe removable at pleasure. Coke and charcoal were burnt, and the insulation was so good, that when the boiler was attached to a gold-leaf electrometer and charged purposely, the divergence of the leaves did not alter either by the presence of a large fire, or the abundant escape of the results of the combustion.

2082. When the issuing steam produces electricity, there are two ways of examining the effect: either the insulated boiler may be observed, or the steam may be examined, but these states are always contrary one to the other. I attached to the boiler both a gold-leaf and a discharging electrometer, the first showed any charge short of a spark, and the second by the number of sparks in a given time carried on the measurement of the electricity evolved. The state of the steam may be observed either by sending it through an insulated wide tube in which are some diaphragms of wire gauze, which serves as a discharger to the steam, or by sending a puff of it near an electrometer when it acts by induction; or by putting wires and plates of conducting matter in its course, and so discharging it. To examine the state of the boiler or substance against which the steam is excited, is far more convenient, as Mr. Armstrong has observed, than to go for the electricity to the steam itself; and in this paper I shall give the state of the former, unless it be otherwise expressed.

2083. Proceeding to the cause of the excitation, I may state first that I have satisfied myself it is not due to evaporation or condensation, nor is it affected by either the one or the other. When the steam was at its full pressure, if the valve were suddenly raised and taken out, no electricity was produced in the boiler, though the evaporation was for the time very great. Again, if the boiler were charged by excited

resin before the valve was opened, the opening of the valve and consequent evaporation did not affect this charge. Again, having obtained the power of constructing steam passages which should give either the positive or the negative, or the neutral state (2102. 2110. 2117.), I could attach these to the steam way, so as to make the boiler either positive, or negative, or neutral at pleasure with the same steam, and whilst the evaporation for the whole time continued the same. So that the excitation of electricity is clearly independent of the evaporation or of the change of state.

2084. The issue of *steam alone* is not sufficient to evolve electricity*. To illustrate this point I may say that the cone apparatus (2077.) is an excellent exciter: so also is a box-wood tube (2102. fig. 5.) soaked in water, and screwed into the steam-globe. If with either of these arrangements, the steam-globe (fig. 1.) be empty of water, so as to catch and retain that which is condensed from the steam, then after the first moment (2089.), and when the apparatus is hot, the issuing steam excites no electricity; but when the steam-globe is filled up so far that the rest of the condensed water is swept forward with the steam, abundance of electricity appears. If then the globe be emptied of its water, the electricity ceases; but upon filling it up to the proper height, it immediately reappears in full force. So when the feeder apparatus (2078.) was used, whilst there was no water in the passage-tube, there was no electricity; but on letting in water from the feeder, electricity was immediately evolved.

2085. The electricity is due entirely to the friction of the particles of water which the steam carries forward against the surrounding solid matter of the passage, or that which, as with the cone (2077.), is purposely opposed to it, and is in its nature like any other ordinary case of excitement by friction. As will be shown hereafter (2130. 2132.), a very small quantity of water properly rubbed against the obstructing or interposed body, will produce a very sensible proportion of electricity.

2086. Of the many circumstances affecting this evolution of electricity, there are one or two which I ought to refer to here. Increase of pressure (as is well illustrated by Mr. Armstrong's experiments) greatly increases the effect, simply by rubbing the two exciting substances more powerfully together. Increase of pressure will sometimes change the positive power of a passage to negative; not that it has power of itself to change the quality of the passage, but as will be seen presently (2108.), by carrying off that which gave the positive power; no increase of pressure, as far as I can find, can change the negative power of a given passage to positive. In other phenomena hereafter to be described (2090. 2105.), increase of pressure will no doubt have its influence; and an effect which has been decreased, or even annihilated (as by the addition of substances to the water in the steam-globe, or to the issuing current of water and steam), may, no doubt, by increase of pressure be again developed and exalted.

2087. The shape and form of the exciting passage has great influence, by favouring

* Mr. Armstrong has also ascertained that water is essential to a high development. Phil. Mag. 1843, vol. xxii. p. 2.

more or less the contact and subsequent separation of the particles of water and the solid substance against which they rub.

2088. When the mixed steam and water pass through a tube or stop-cock (2076.), they may issue, producing either a hissing smooth sound, or a rattling rough sound*; and with the cone apparatus (2077. fig. 2.), or certain lengths of tube, these conditions alternate suddenly. With the smooth sound little or no electricity is produced; with the rattling sound plenty. The rattling sound accompanies that irregular rough vibration, which casts the water more violently and effectually against the substance of the passage, and which again causes the better excitation. I converted the end of the passage into a steam-whistle, but this did no good.

2089. If there be no water in the steam-globe (2076.), upon opening the steam-cock the *first effect* is very striking; a good excitement of electricity takes place, but it very soon ceases. This is due to water condensed in the cold passages, producing excitement by rubbing against them. Thus, if the passage be a stop-cock, whilst cold it excites electricity with what is supposed to be steam only; but as soon as it is hot, the electricity ceases to be evolved. If, then, whilst the steam is issuing, the cock be cooled by an insulated jet of water, it resumes its power. If, on the other hand, it be made hot by a spirit-lamp before the steam be let on, then there is *no* first effect. On this principle, I have made an exciting passage by surrounding one part of an exit tube with a little cistern, and putting spirits of wine or water into it.

2090. We find then that particles of water rubbed against other bodies by a current of steam evolve electricity. For this purpose, however, it is not merely water but *pure* water which must be used. On employing the feeding apparatus (2078.), which supplied the rubbing water to the interior of the steam passage, I found, as before said, that with steam only I obtained no electricity (2084.). On letting in distilled water, abundance of electricity was evolved; on putting a small crystal of sulphate of soda, or of common salt into the water, the evolution ceased entirely. Re-employing distilled water, the electricity appeared again; on using the common water supplied to London, it was unable to produce it.

2091. Again, using the steam-globe (2076.), and a box-wood tube (2102.) which excites well if the water distilling over from the boiler be allowed to pass with the steam, when I put a small crystal of sulphate of soda, of common salt, or of nitre, or the smallest drop of sulphuric acid, into the steam-globe with the water, the apparatus was utterly ineffective, and no electricity could be produced. On withdrawing such water and replacing it by distilled water, the excitement was again excellent: on adding a very small portion of any of these substances, it ceased; but upon again introducing pure water it was renewed.

* Messrs. Armstrong and Schafhaeutl have both observed the coincidence of certain sounds or noises with the evolution of the electricity.

2092. Common water in the steam-globe was powerless to excite. A little potash added to distilled water took away all its power; so also did the addition of *any* of those saline or other substances which give conducting power to water.

2093. The effect is evidently due to the water becoming so good a conductor, that upon its friction against the metal or other body, the electricity evolved can be immediately discharged again, just as if we tried to excite lac or sulphur by flannel which was damp instead of dry. It shows very clearly that the exciting effect, when it occurs, is due to water and not to the passing steam.

2094. As ammonia increases the conducting power of water only in a small degree (554.), I concluded that it would not take away the power of excitement in the present case; accordingly on introducing some to the pure water in the globe, electricity was still evolved though the steam of vapour and water was able to redden moist turmeric paper. But the addition of a very small portion of dilute sulphuric acid, by forming sulphate of ammonia, took away all power.

2095. When, in any of these cases, the steam-globe contained water which could not excite electricity, it was beautiful to observe how, on opening the cock which was inserted into the steam-pipe before the steam-globe, fig. 1. (the use of which was to draw off the water condensed in the pipe before it entered the steam-globe), electricity was instantly evolved; yet a few inches further on the steam was quite powerless, because of the small change in the quality of the water over which it passed, and which it took with it.

2096. When a wooden or metallic tube (2076.) was used as the exciting passage, the application of solution of salts to the outside and end of the tube in no way affected the evolution. But when a wooden cone (2077.) was used, and that cone moistened with the solutions, there was no excitement on first letting out the steam, and it was only as the solution was washed away that the power appeared; soon rising, however, to its full degree.

2097. Having ascertained these points respecting the necessity of water and its purity, the next for examination was the influence of the substance against which the stream of steam and water rubbed. For this purpose I first used cones (2077.) of various substances, either insulated or not, and the following, namely, brass, boxwood, beech-wood, ivory, linen, kerseymere, white silk, sulphur, caoutchouc, oiled silk, japanned leather, melted caoutchouc and resin, all became negative, causing the stream of steam and water to become positive. The fabrics were applied stretched over wooden cones. The melted caoutchouc was spread over the surface of a boxwood or a linen cone, and the resin cone was a linen cone dipped in a strong solution of resin in alcohol, and then dried. A cone of wood dipped in oil of turpentine, another cone soaked in olive oil, and a brass cone covered with the alcoholic solution of resin and dried, were at first inactive, and then gradually became negative, at which

time the oil of turpentine, olive-oil and resin were found cleared off from the parts struck by the stream of steam and water. A cone of kerseymere, which had been dipped in alcoholic solution of resin and dried two or three times in succession, was very irregular, becoming positive and negative by turns, in a manner difficult to comprehend at first, but easy to be understood hereafter (2113.).

2098. The end of a rod of shell-lac was held a moment in the stream of steam and then brought near a gold-leaf electrometer: it was found excited negative, exactly as if it had been rubbed with a piece of flannel. The corner of a plate of sulphur showed the same effect and state when examined in the same way.

2099. Another mode of examining the substance rubbed was to use it in the shape of wires, threads or fragments, holding them by an insulating handle in the jet, whilst they were connected with a gold-leaf electrometer. In this way the following substances were tried:—

Platinum,	Horse-hair,	Charcoal,
Copper,	Bear's hair,	Asbestus,
Iron,	Flint glass,	Cyanite,
Zinc,	Green glass,	Hæmatite,
Sulphuret of copper,	Quill,	Rock-crystal,
Linen,	Ivory,	Orpiment,
Cotton,	Shell-lac on silk,	Sulphate of baryta,
Silk,	Sulphur on silk,	Sulphate of lime,
Worsted,	Sulphur in piece,	Carbonate of lime,
Wood,	Plumbago,	Fluor-spar.

All these substances were rendered negative, though not in the same degree. This apparent difference in degree did not depend *only* upon the specific tendency to become negative, but also upon the conducting power of the body itself, whereby it gave its charge to the electrometer; upon its tendency to become wet (which is very different, for instance in shell-lac or quill, to that of glass or linen), by which its conducting quality was affected; and upon its size or shape. Nevertheless I could distinguish that bear's hair, quill and ivory had very feeble powers of exciting electricity as compared to the other bodies.

2100. I may make here a remark or two upon the introduction of bodies into the jet. For the purpose of preventing condensation on the substance, I made a platinum wire white-hot by an insulated voltaic battery, and introduced it into the jet: it was quickly lowered in temperature by the stream of steam and water to 212°, but of course could never be below the boiling point. No difference was visible between the effect at the first instant of introduction or any other time. It was always instantly electrified and negative.

2101. The threads I used were stretched across a fork of stiff wire, and the middle part of the thread was held in the jet of vapour. In this case, the string or thread, if held exactly in the middle of the jet and looked at end-ways to the thread, was

seen to be still, but if removed the least degree to the right or left of the axis of the stream it (very naturally) vibrated, or rather rotated, describing a beautiful circle, of which the axis of the stream was the tangent: the interesting point was to observe, that when the thread rotated, travelling as it were with the current, there was little or no electricity evolved, but that when it was nearly or quite stationary there was abundance of electricity, thus illustrating the effect of friction.

2102. The difference in the quality of the substances above described (2099.) gives a valuable power of arrangement at the jet. Thus if a metal, glass, or wood tube* (2076.) be used for the steam issue, the boiler is rendered well negative and the steam highly positive; but if a quill tube or, better still, an ivory tube be used, the boiler receives scarcely any charge, and the stream of steam is also in a neutral state. This result not only assists in proving that the electricity is not due to evaporation, but is also very valuable in the experimental inquiry. It was in such a neutral jet of steam and water that the excitation of the bodies already described (2099.) was obtained.

2103. Substances, therefore, may be held either in the neutral jet from an ivory tube, or in the positive jet from a wooden or metal tube; and in the latter case effects occurred which, if not understood, would lead to great confusion. Thus an insulated wire was held in the stream issuing from a glass or metal tube, about half an inch from the mouth of the tube, and was found to be unexcited: on moving it in one direction a little further off, it was rendered positive; on moving it in the other direction, nearer to the tube, it was negative. This was simply because, when near the tube in the forcible part of the current, it was excited and rendered negative, rendering the steam and water more positive than before, but that when further off, in a quieter part of the current, it served merely as a discharger to the current previously excited in the exit tube, and so showed the same state with it. Platinum, copper, string, silk, wood, plumbago, or any of the substances mentioned above (2099.), excepting quill, ivory, and bear's hair, could, in this way, be made to assume either one state or the other, according as they were used as exciters or dischargers, the difference being determined by their place in the stream. A piece of fine wire gauze held across the issuing jet shows the above effect very beautifully; the difference of an eighth of an inch either way from the neutral place will change the state of the wire gauze.

2104. If, instead of an excited jet of steam and water (2103.), one issuing from an ivory tube (2102.), and in the neutral state be used, then the wires, &c. can no longer be made to assume both states. They may be excited and rendered negative (2099.), but at no distance can they become dischargers, or show the positive state.

2105. We have already seen that the presence of a very minute quantity of matter able to give conducting power to the water took away all power of excitation (2090,

* A box-wood tube, 3 inches long and $\frac{1}{5}$th of an inch inner diameter, well soaked in distilled water and screwed into the steam-globe, is an admirable exciter.

&c.) up to the highest degree of pressure, i. e. of mechanical friction that I used (2086.); and the next point was to ascertain whether it would be so for all the bodies rubbed by the stream, or whether differences in degree would begin to manifest themselves. I therefore tried all these bodies again, at one time adding about two grains of sulphate of soda to the four ounces of water which the steam-globe retained as a constant quantity when in regular action, and at another time adding not a fourth of this quantity of sulphuric acid (2091.). In both cases all the substances (2099.) remained entirely unexcited and neutral. Very probably, great increase of pressure might have developed some effect (2086.).

2106. With dilute sulphuric acid in the steam-globe, varying from extreme weakness to considerable sourness, I used tubes and cones of zinc, but could obtain *no trace* of electricity. Chemical action, therefore, appears to have nothing to do with the excitement of electricity by a current of steam.

2107. Having thus given the result of the friction of the steam and water against so many bodies, I may here point out the remarkable circumstance of water being *positive* to them all. It very probably will find its place above all other substances, even cat's hair and oxalate of lime (2131.). We shall find hereafter, that we have power, not merely to prevent the jet of steam and water from becoming positive, as by using an ivory tube (2102.), but also of reducing its own power when passing through or against such substances as wood, metal, glass, &c. Whether, with a jet so reduced, we shall still find amongst the bodies above mentioned (2099.) some that can render the stream positive and others that can make it negative, is a question yet to be answered.

2108. Advancing in the investigation, a new point was to ascertain what other bodies, than water, would do if their particles were carried forward by the current of steam. For this purpose the feeding apparatus (2078.) was mounted and charged with oil of turpentine, to be let in at pleasure to the steam-exit passage. At first the feeder stop-cock was shut, and the issuing steam and water made the boiler negative. On letting down the oil of turpentine, this state was instantly changed, the boiler became powerfully positive, and the jet of steam, &c. as strongly negative. Shutting off the oil of turpentine, this state gradually fell, and in half a minute the boiler was negative, as at first. The introduction of more oil of turpentine instantly changed this to positive, and so on with perfect command of the phenomena.

2109. Removing the feeder apparatus and using only the steam-globe and a wooden exit tube (2076.), the same beautiful result was obtained. With pure water in the globe the boiler was negative, and the issuing steam, &c. positive; but a drop or two of oil of turpentine, introduced into the steam-globe with the water, instantly made the boiler positive and the issuing stream negative. On using the little interposed chamber C (2079.), the effects were equally decided. A piece of clean new sail-cloth

was formed into a ring, moistened with oil of turpentine and placed in the box; as long as a trace of the fluid remained in the box the boiler was positive and the issuing stream negative.

2110. Thus the positive or negative state can be given at pleasure, either to the substance rubbed or to the rubbing stream; and with respect to this body, oil of turpentine, its perfect and ready dissipation by the continuance of the passage of the steam soon causes the new effect to cease, yet with the power of renewing it in an instant.

2111. With olive oil the same general phenomena were observed, i. e. it made the stream of steam, &c. *negative*, and the substance rubbed by it *positive*. But from the comparative fixedness of oil, the state was much more permanent, and a very little oil introduced into the steam-globe (2076.), or into the chamber C (2079.), or into the exit tube, would make the boiler positive for a long time. It required, however, that this oil should be in such a place that the steam stream, after passing by it, should rub against other matter. Thus, on using a wooden tube (2076. 2102.) as the exciter, if a little oil were applied to the inner termination, or that at which the steam entered it, the tube was made positive and the issuing steam negative; but if the oil were applied to the outer termination of the tube, the tube had its ordinary negative state, as with pure water, and the issuing steam was positive.

2112. Water is essential to this excitation by fixed oil, for when the steam-globe was emptied of water, and yet oil left in it and in the passages, there was no excitement. The first effect (2089.), it is true, was one of excitement, and it rendered the boiler positive, but that was an effect due to the water condensed in the passage, combined with the action of the oil. Afterwards, when all was hot, there was no evolution of electricity.

2113. I tried many other substances with the chamber C and other forms of apparatus, using the wet wooden tube (2102.) as the place and substance by which to excite the steam stream. Hog's-lard, spermaceti, bees'-wax, castor-oil, resin applied dissolved in alcohol; these, with olive-oil, oil of turpentine, and oil of laurel, all rendered the boiler positive, and the issuing steam negative. Of substances which seemed to have the reverse power, it is doubtful if there are any above water. Sulphuret of carbon, naphthaline, sulphur, camphor, and melted caoutchouc, occasionally seemed in strong contrast to the former bodies, making the boiler very negative, but on trying pure water immediately after, it appeared to do so quite as powerfully. Some of the latter bodies with oil-gas liquid, naphtha and caoutchoucine, gave occasionally variable results, as if they were the consequence of irregular and complicated effects. Indeed, it is easy to comprehend, that according as a substance may adhere to the body rubbed, or be carried off by the passing stream, exchanging its mechanical action from rubbed to rubber, it should give rise to variable effects; this, I think, was the case with the cone and resin before referred to (2097.).

2114. The action of salts, acids, &c., when present in the water to destroy its

effect, I have already referred to (2090, &c.). In addition, I may note that sulphuric ether, pyroxylic spirit, and boracic acid did the same.

2115. Alcohol seemed at the first moment to render the boiler positive. Half alcohol and half water rendered the boiler negative, but much less so than pure water.

2116. It must be considered that a substance having the reverse power of water, but only in a small degree, may be able to indicate that property merely by diminishing the power of water. This diminution of power is very different in its cause to that dependent on increasing the conducting power of the water, as by saline matter (2090.), and yet the apparent effect will be the same.

2117. When it is required to render the issuing steam permanently negative, the object is very easily obtained. A little oil or wax put into the steam-globe (2076.), or a thick ring of string or canvas soaked in wax, or solution of resin in alcohol, and introduced into the box C (2079.), supplies all that is required. By adjusting the application it is easy to neutralize the power of the water, so that the issuing stream shall neither become electric, nor cause that to be electrified against which it rubs.

2118. We have arrived, therefore, at three modes of rendering the jet of steam and water neutral, namely, the use of an ivory or quill tube (2102.), the presence of substances in the water (2090, &c.), and the neutralization of its natural power by the contrary force of oil, resin, &c. &c.

2119. In experiments of the kind just described an ivory tube cannot be used safely with acid or alkalies in the steam-globe, for they, by their chemical action on the substance of the tube, in the evolution or solution of the oily matter for instance, change its state and make its particular power of excitement very variable. Other circumstances also powerfully affect it occasionally (2144.).

2120. A very little oil in the rubbing passages produces a great effect, and this at first was a source of considerable annoyance, by the continual occurrence of unexpected results; a portion may lie concealed for a week together in the thread of an unsuspected screw, and yet be sufficient to mar the effect of every arrangement. Digesting and washing with a little solution of alkali, and avoiding all oiled washers, is the best way in delicate experiments of evading the evil. Occasionally I have found that a passage, which was in some degree persistently negative, from a little melted caoutchouc, or positive from oil, resin, &c., might be cleared out thoroughly by letting oil of turpentine be blown through it; it assumed for a while the positive state, but when the continuance of steam had removed that (2110.), the passage appeared to be perfectly clear and good and in its normal condition.

2121. I now tried the effect of oil, &c. when a little saline matter or acid was added to the water in the steam-globe (2090, &c.), and found that when the water was in such a state as to have no power of itself, still oil of turpentine, or oil, or resin in the box C, showed their power, in conjunction with such water, of rendering the

boiler positive, but their power appeared to be reduced: increase of the force of steam, as in all other cases, would, there is little doubt, have exalted it again. When alkali was in the steam-globe, oil and resin lost very much of their power, and oil of turpentine very little. This fact will be important hereafter (2126.).

2122. We have seen that the action of such bodies as oil introduced into the jet of steam changed its power (2108.), but it was only by experiment we could tell whether this change was to such an extent as to alter the electricity for few or many of the bodies against which the steam stream rubbed. With olive oil in the box C, *all* the insulated cones before enumerated (2097.) were made positive. With acetic acid in the steam-globe all were made neutral (2091.). With resin in the box C (2113.), all the substances in the former list (2099.) were made positive, there was not one exception.

2123. The remarkable power of oil, oil of turpentine, resin, &c., when in very small quantity, to change the exciting power of water, though as regards some of them (2112.) they are inactive without it, will excuse a few theoretical observations upon their mode of action. In the first place it appears that steam alone cannot by friction excite the electricity, but that the minute globules of water which it carries with it being swept over, rubbed upon and torn from the rubbed body (2085.) excite it and are excited, just as when the hand is passed over a rod of shell-lac. When olive oil or oil of turpentine is present, these globules are, I believe, virtually converted into globules of these bodies, and it is no longer water, but the new fluids which are rubbing the rubbed bodies.

2124. The reasons for this view are the following. If a splinter of wood dipped in olive oil or oil of turpentine touch the surface of water, a pellicle of the former instantly darts and spreads over the surface of the latter. Hence it is pretty certain that every globule of water passing through the box C, containing olive oil or oil of turpentine, will have a pellicle over it. Again, if a metal, wooden, or other balance-pan be *well cleaned* and *wetted* with water, and then put on the surface of clean water in a dish, and the other pan be loaded until almost, but not quite able to pull the first pan from the water, it will give a rough measure of the cohesive force of the water. If now the oily splinter of wood touch any part of the clean surface of the water in the dish, not only will it spread over the whole surface, but cause the pan to separate from the water, and if the pan be put down again, the water in the dish will no longer be able to retain it. Hence it is evident that the oil facilitates the separation of the water into parts by a mechanical force not otherwise sufficient, and invests these parts with a film of its own substance.

2125. All this must take place to a great extent in the steam passage: the particles of water there must be covered each with a film of oil. The tenuity of this film is no objection to the supposition, for the action of excitement is without doubt at

that surface where the film is believed to exist, and such a globule, though almost entirely water, may well act as an oil globule, and by its friction render the wood, &c. positive, itself becoming negative.

2126. That water which is rendered ineffective by a little saline or acid matter should still be able to show the effect of the film of oil (2121.) attached to it, is perfectly consistent with this view. So also is the still more striking fact that alkalized water (2092.) having no power of itself should deeply injure the power of olive oil or resin, and hardly touch that of oil of turpentine (2121.), for the olive oil or resin would no longer form a film over it but dissolve in it, on the contrary the oil of turpentine would form its film.

2127. That resin should produce a strong effect and sulphur not is also satisfactory, for I find resin in boiling hot water melts, and has the same effect on the balance (2124.) as oil, though more slowly; but sulphur has not this power, its point of fusion being too high.

2128. It is very probable that when wood, glass, or even metal is rubbed by these oily currents, the oil may be considered as rubbing not merely against wood, &c., but water also, the water being now on the side of the thing rubbed. Under the circumstances water has much more attraction for the wood rubbed than oil has, for in the steam-current, canvas, wood, &c. which has been well soaked in oil for a long time are quickly dispossessed of it, and found saturated with water. In such case the effect would still be to increase the positive state of the substance rubbed, and the negative state of the issuing stream.

2129. Having carried the experiments thus far with steam, and having been led to consider the steam as ineffectual by itself, and merely the mechanical agent by which the rubbing particles were driven onwards, I proceeded to experiment with compressed air*. For this purpose I used a strong copper box of the capacity of forty-six cubic inches, having two stop-cocks, by one of which the air was always forced in, and the other retained for the exit aperture. The box was very carefully cleaned out by caustic potash. Extreme care was taken (and required) to remove and avoid oil, wax, or resin about the exit apertures. The air was forced into it by a condensing syringe, and in certain cases when I required dry air, four or five ounces of cylinder potassa fusa were put into the box, and the condensed air left in contact with the substance ten or fifteen minutes. The average quantity of air which issued and was used in each blast was 150 cubic inches. It was very difficult to deprive this air of the smell of oil which it acquired in being pumped through the condensing syringe.

2130. I will speak first of undried common air: when such compressed air was

* Mr. Armstrong has also employed air in much larger quantities. Philosophical Magazine, 1841, vol. xviii. pp. 133, 328.

let suddenly out against the brass or the wood cone (2077.), it rendered the cone negative, exactly as the steam and water had done (2097.). This I attributed to the particles of water suddenly condensed from the expanding and cooled air rubbing against the metal or wood: such particles were very visible in the mist that appeared, and also by their effect of moistening the surface of the wood and metal. The electricity here excited is quite consistent with that evolved by steam and water: but the idea of that being due to evaporation (2083.) is in striking contrast with the actual condensation here.

2131. When however common air was let out against ice it rendered the ice *positive*, again and again, and that in alternation with the negative effect upon wood and metal. This is strongly in accordance with the high positive position which has already been assigned to water (2107.).

2132. I proceeded to experiment with dry air (2129.), and found that it was in all cases quite *incapable* of exciting electricity against wood or sulphur, or brass, in the form of cones (2077. 2097.); yet if, in the midst of these experiments, I let out a portion of air immediately after its compression, allowing it no time to dry, then it rendered the rubbed wood or brass negative (2130.). This is to me a satisfactory proof that in the former case the effect was due to the condensed water, and that neither *air alone* nor *steam alone* can excite these bodies, wood, brass, &c., so as to produce the effect now under investigation.

2133. In the next place the box C was attached to this air apparatus and experiments made with different substances introduced into it (2108.), using common air as the carrying vehicle.

2134. With distilled water in C, the metal cone was every now and then rendered negative, but more frequently no effect was produced. The want of a continuous jet of air sadly interfered with the proper adjustment of the proportion of water to the issuing stream.

2135. With common water (2090.), or a very dilute saline solution, or very dilute sulphuric acid (2091.) or ammonia, I never could obtain any traces of electricity.

2136. With oil of turpentine only in box C, the metal cone was rendered positive; but when both distilled water and oil of turpentine were introduced, the cone was very *positive*, indeed far more so than before. When sent against ice, the ice was made positive.

2137. In the same manner olive oil and water in C, or resin in alcohol and water in C, rendered the cone positive, exactly as if these substances had been carried forward in their course by steam.

2138. Although the investigation as respects the steam stream may here be considered as finished, I was induced in connection with the subject to try a few experiments with the air current and dry powders. *Sulphur* in powder (sublimed) rendered

both metal and wood, and even the sulphur cone negative, only once did it render metal positive. *Powdered resin* generally rendered metal negative, and wood positive, but presented irregularities, and often gave *two states in the same experiment,* first diverging the electrometer leaves, and yet at the end leaving them uncharged. *Gum* gave unsteady and double results like the resin. *Starch* made wood negative. *Silica,* being either very finely powdered rock-crystal or that precipitated from fluo-silicic acid by water, gave very constant and powerful results, but both metal and wood were made strongly positive by it, and the silica when caught on a wet insulated board and examined was found to be negative.

2139. These experiments with powders give rise to two or three observations. In the first place the high degree of friction occurring between particles carried forward by steam or air was well illustrated by what happened with sulphur: it was found driven into the dry box-wood cone opposed to it with such force that it could not be washed or wiped away, but had to be removed by scraping. In the next place, the *double* excitements were very remarkable. In a single experiment, the gold leaves would open out very wide at first, and then in an instant as suddenly fall, whilst the jet still continued, and remains at last either neutral or a very little positive or negative: this was particularly the case with gum and resin. The fixation upon the wood of some of the particles issuing at the beginning of the blast and the condensation of moisture by the expanding air, are circumstances which with others present tend to cause these variable results.

2140. Sulphur is nearly constant in its results, and silica very constant, yet their states are the reverse of those that might have been expected. Sulphur in the lump is rendered negative whether rubbed against wood or any of the metals which I have tried, and renders them *positive* (2141.), yet in the above experiments it almost always made both negative. Silica, in the form of a crystal, by friction with wood and metals renders them *negative,* but applied as above, it constantly made them strongly positive. There must be some natural cause for these changes, which at present can only be considered as imperfect results, for I have not had time to investigate the subject.

2141. In illustration of the effect produced by steam and water striking against other bodies, I rubbed these other substances (2099.) together in pairs to ascertain their order, which was as follows:—

1. Catskin or bearskin.	8. Linen, canvas.	
2. Flannel.	9. White silk.	
3. Ivory.	10. The hand.	Iron.
4. Quill.	11. Wood.	Copper.
5. Rock-crystal.	12. Lac.	Brass.
6. Flint glass.	13. Metals . . .	Tin.
7. Cotton.	14. Sulphur.	Silver.
		Platinum.

Any one of these became negative with the substances above, and positive with those beneath it. There are however many exceptions to this general statement: thus one part of a catskin is very negative to another part, and even to rock-crystal: different pieces of flannel also differ very much from each other.

2142. The mode of rubbing also makes in some cases a great difference, although it is not easy to say why, since the particles that actually rub ought to present the same constant difference; a feather struck lightly against dry canvas will become strongly negative, and yet the same feather drawn with a little pressure between the folds of the same canvas will be strongly positive, and these effects alternate, so that it is easy to take away the one state in a moment by the degree of friction which produces the other state. When a piece of flannel is halved and the two pieces drawn across each other, the two pieces will have different states irregularly, or the same piece will have both states in different parts, or sometimes both pieces will be negative, in which case, doubtless, air must have been rendered positive, and then dissipated.

2143. Ivory is remarkable in its condition. It is very difficult of excitement by friction with the metals, much more so than linen, cotton, wood, &c., which are lower in the scale than it (2141.), and withal are much better conductors, yet both circumstances would have led to the expectation that it would excite better than them when rubbed with metals. This property is probably very influential in giving character to it as a non-exciting steam passage (2102.).

2144. Before concluding this paper, I will mention, that having used a thin ivory tube fixed in a cork (2076.) for many experiments with oil, resin, &c., it at last took up such a state as to give not merely a non-exciting passage for the steam, but to exert upon it a nullifying effect, for the jet of steam and water passing through it produced no excitation against any of the bodies opposed, as on the former occasion, to it (2099.). The tube was apparently quite clean, and was afterwards soaked in alcohol to remove any resin, but it retained this peculiar state.

2145. Finally, I may say that the cause of the evolution of electricity by the liberation of confined steam is not evaporation ; and further, being, I believe, friction, it has no effect in producing, and is not connected with, the general electricity of the atmosphere: also, that as far as I have been able to proceed, pure gases, *i. e.* gases not mingled with solid or liquid particles, do not excite electricity by friction against solid or liquid substances*.

* References to papers in the Philosophical Magazine, 1840–1843. Armstrong, Phil. Mag. vol. xvii. pp. 370, 452; vol. xviii. pp. 50, 133, 328; vol. xix. p. 25; vol. xx. p. 5; vol. xxii. p. 1. Pattinson, Phil. Mag. vol. xvii. pp. 375, 457. Schafhaeutl, Phil. Mag. vol. xvii. p. 449; vol. xviii. pp. 14, 95, 265.

PLATE I.

Description of the Apparatus represented in section, and to a scale of one-fourth.

Fig. 1. The steam-globe (2076.), principal steam-cock, and drainage-cock to remove the water condensed in the pipe. The current of steam, &c. travelled in the direction of the arrow-heads.

Fig. 2. The cone apparatus (2077.) in one of its forms. The cone could be advanced and withdrawn by means of the milled head and screw.

Fig. 3. The feeding apparatus (2078.). The feeder was a glass tube or retort neck fitted by a cork into the cap of the feeding stop-cock. Other apparatus, as that figured 2, 5, 6, could be attached by a connecting piece to this apparatus.

Fig. 4. The chamber C (2079.) fitted by a cork on to a metal pipe previously screwed into the steam-globe; and having a metallic tube and adjusting piece screwed into its mouth. Other parts, as the cone fig. 2, or the wooden or glass tubes 5, 6, could be conjoined with this chamber.

Fig. 5. The box-wood tube (2102.).

Fig. 6. A glass or thin metal tube (2076.) attached by a cork to a mouth-piece fitting into the steam-globe.

Fig. 1.

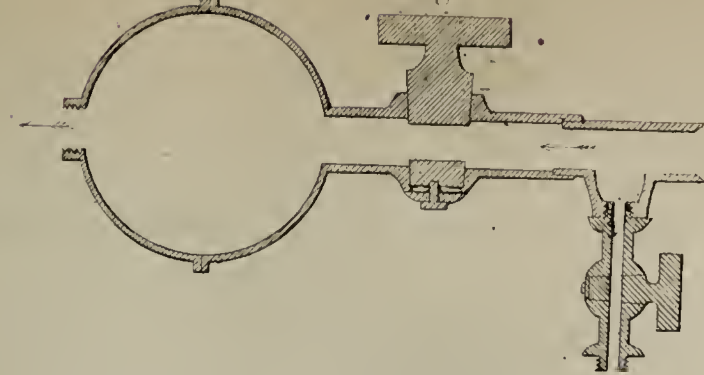


Fig. 2.

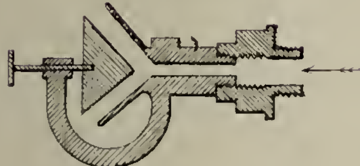


Fig. 4.

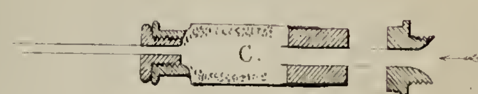


Fig. 3.

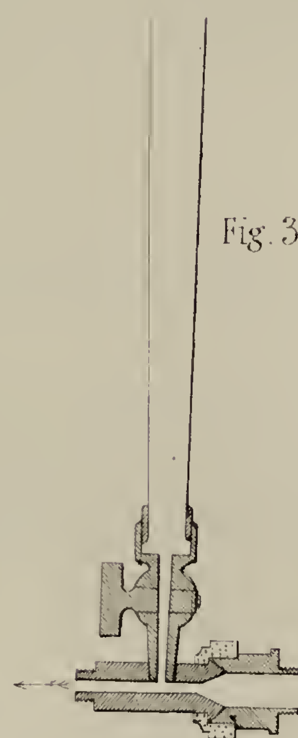


Fig. 5.

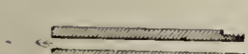


Fig. 6.

Experimental Researches in Electricity XVIII. *Series.*

J. Basire Lith.

IV. *Spermatozoa observed within the Mammiferous Ovum.*

By Martin Barry, *M.D., F.R.SS. L. and E.*

Received November 24,—Read December 8, 1842.

As the results of my researches in Embryology have all been communicated to the Royal Society*, it seems proper to offer to its notice a single observation which I have lately made.

On a former occasion† I stated that at certain periods an orifice was sometimes visible in the thick transparent membrane ("*zona pellucida*") of the mammiferous ovum; and that once I had seen an object very much resembling a spermatozoon in the orifice. But spermatozoa, so far as I am aware, have never been described as seen *within* the ovum of any animal. It may therefore be interesting to physiologists to be informed that about a fortnight since, in examining some ova of the Rabbit of twenty-four hours, from the Fallopian tube,—in which the orifice above-mentioned was no longer visible,—I unexpectedly discerned a number of spermatozoa in their interior. These ova were submitted to the inspection of Professor Owen, and I afterwards showed one of them to Professors Sharpey and Grainger, all of whom agreed that the spermatozoa were *contained within the ovum*‡.

London, 21st November, 1842.

* Philosophical Transactions, 1838–39–40–41.

† Ibid. 1840, p. 533.

‡ [The ova were in that state in which the essential part—the germ—consists of two cells. The spermatozoa lay around and between these cells; and when the ova were first examined I thought I discerned traces of spermatozoa even *within* the cells.

While the paper is going through the press, the opportunity is afforded me for mentioning that I have this day confirmed the observation above recorded; several ova from the Fallopian tube of another rabbit, in a somewhat earlier stage, having presented spermatozoa in their interior;—i. e. (as in the first observation) within the thick transparent membrane ("*zona pellucida*") brought with the ovum from the ovary.—31st March, 1843.]

V. *Observations on certain cases of Elliptic Polarization of Light by Reflexion. By the Rev.* Baden Powell, *M.A., F.R.S., F.G.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford.*

Received November 10, 1842,—Read January 26, 1843.

Introduction.

THE peculiar character impressed on light, originally polarized in a plane inclined to that of incidence and reflected from a metallic surface, discovered by Sir D. Brewster*, and named by him elliptic polarization, has been since shown to coincide with what, from a different analogy, is termed elliptic polarization in the undulatory theory; and which is also exhibited by an interposed plate of mica, or by total internal reflexion, as in Fresnel's rhomb.

The most distinct experimental test of the existence of this property and a measure of its amount, is the well-known *dislocation* of the polarized rings, seen by a plate of calc-spar and a tourmaline, in light of this kind. And this, as in other similar cases, is represented theoretically by a formula for the intensity at any part of the plate, *in the case of the rhomb*, for *circular* polarization, as in Mr. Airy's tract on the undulatory theory (Art. 160.); and for *elliptic*, as in the same author's paper on quartz†. A general formula for the rings in light of all degrees of ellipticity, *not* restricted by the peculiar conditions of the *rhomb*, has not been hitherto published: but I am indebted to Mr. Airy for the communication of such a formula, which will be given in the sequel, as leading to some remarkable applications.

With immediate reference to the experiments of Sir D. Brewster *on thin films*‡, Professor Lloyd, in 1841, investigated on the principles of the undulatory theory, the general case of light previously polarized in any azimuth, and reflected from a thin plate, at any angle; and by generalizing the methods of M. Poisson, found expressions both for the intensity, the changes corresponding to different incidences, and the phase of vibration of the pencils reflected from the two surfaces, which in general differ in retardation and are polarized, one in the plane of reflexion and the other perpendicular to it: whence it follows that the resulting light should be in general *elliptically polarized*§.

Professor Lloyd's theory seems completely to explain the various phenomena ob-

* Philosophical Transactions, 1830.

† Cambridge Transactions, 1831.

‡ Philosophical Transactions, 1840.

§ See Reports of British Association, 1841, Sectional Proceedings, p. 26.

served by Sir D. BREWSTER, including those of Mr. AIRY* on the colours of thin plates in polarized light. But Professor LLOYD also infers the further application of the same principles to the case of elliptic polarization in the reflexion from polished metals, on the hypothesis that their superficial laminæ may be regarded as thin plates, or at least act in an analogous manner.

Before I was acquainted with Professor LLOYD's *theoretical* investigations, I had pursued an *experimental* examination of the phenomena of elliptic polarization in the reflexion from various surfaces, in the course of which I was led to some cases which seem to have a more special bearing upon theory, particularly in connexion with the views just referred to.

My observations were all conducted by the method of observing the modifications of the polarized rings under different conditions, both of surface and of incidence; and were directed to ascertaining both the *existence* and *amount* of ellipticity shown by the dislocation of those rings, as also to the peculiar character indicated by the *direction* in which the dislocation takes place; the protrusion of the alternate quadrants appearing in certain cases in one direction and in others in the opposite.

The observations are reducible to two classes:—1st, those designed to contribute to the inquiry *what substances* possess the property of elliptic polarization ?, by examining the light reflected from various bodies; of which I here notice only a few cases which appeared remarkable; 2ndly, observations on certain cases of *films* of several kinds, including those formed on metal by oxidation, or other action upon the metal itself, as well as by extraneous deposition. In these cases the ellipticity generally exists in different degrees, and with different characters as to direction, while in some instances it is destroyed or reduced to plane polarization.

I at first noticed these effects as produced in some cases of highly polished metal which had become tarnished by long exposure, and in which iridescent films had formed on the surface without destroying the polish. And again, in trying the effect of *heating* a metal plate, while observing the rings, I found the ellipticity disappear, but soon perceived that the effect was due to the coloured films formed on the surface, and remained when the plate was cold. I was thus led to institute more exact experiments of the same kind, in which the tints were formed in regular succession, as well as to examine steel in different stages of tempering.

From these cases I was naturally led to those of the films of metallic deposit produced by the galvanic process of NOBILI; specimens of which were kindly furnished me by Dr. DAUBENY. In these films it is well known the colours follow, at least generally, the orders of NEWTON's scale; the thickest film being deposited where the action is most intense, or where the surfaces in connexion with the two poles most nearly approach one another. In all these instances, then, I had a succession of films formed upon metal, in which the changes effected in the polarization could be traced in regular order.

* Cambridge Transactions, 1832.

The general result in all these cases, is that, *from any one tint to another, through each entire order of tints, the form of the rings in the reflected light undergoes certain regular changes, passing from a dislocation in one direction, to that in the opposite, through an intermediate point of no dislocation, or of plane polarization : and this, exhibiting a dark and a bright centred system alternately, as long as the orders of tints are preserved pure.*

Now these are precisely the changes in the form of the rings expressed by successive modifications of Mr. Airy's formula, corresponding to the increments in the retardation which belong to the periodical colours of the films.

In the instance of the metallic films it is a question whether in any case the existence of elliptic polarization be due to the action of the film simply, or whether the subjacent metallic surface have any share in producing it, while the film acts as a retarding plate, which would render the conception of the mode of action more complex.

These are points on which, perhaps, at present we cannot form a decisive opinion. But the fact that the ellipticity, to whatever cause it may be due, undergoes the changes just mentioned, affords an interesting comparison with theory, and may aid future advances towards a knowledge of the nature of the action which produces elliptic polarization in these cases.

Apparatus and Method of experimenting.

The arrangement of my apparatus was, essentially, as follows : the light was polarized by transmission through a Nicol-prism ; this was attached to a small graduated arc, so that it could be adjusted to throw the polarized ray at any required incidence on the surface under examination ; and could be turned about its own axis, so that the plane of polarization might be inclined to that of incidence.

After reflexion, the ray was received by an analysing apparatus, containing a plate of calc-spar and a tourmaline, capable of a corresponding adjustment to different inclinations, by which were exhibited the polarized rings in the several modifications they underwent in different cases. This part had also a motion about its own axis, measured by a graduated circle. It will hardly be necessary to state more details as to the construction of the apparatus, except perhaps to observe that an arrangement, by which the surface under examination could be slid horizontally under the polarizing apparatus, was necessary when the object was to examine the changes presented in passing from one part of some surfaces to another.

In many cases where the reflexion from parts of a surface of varying character was to be examined, I fitted to the eye-piece a lens of short focus, between the calc-spar and the reflecting surface, which enabled me to see with great distinctness the rings in light from very small portions of the surface, which could be isolated by covering the rest.

In all cases the analyser is supposed in the position to give the dislocated rings with

the nearest approach to the dark cross with the plain metal; the circular systems alone being precisely described as dark or bright centred.

The direction of dislocation is distinguished by the quadrants in which the dark patches near the centre occur. The position of the line joining them, upon plain metal, is taken as the zero for comparison in other cases.

The observations were repeated at several different incidences, but for the purpose of the comparisons here in view, it suffices to give the results at one incidence, the relative appearances at others being similar. They are arranged in a tabular form in each case.

Observations.—Professor Forbes's *Mica.*

The original observations of Sir D. Brewster were confined to pure metals and a few metallic ores; in all which the ellipticity is insensible at incidences less than about 30°, and comes to a maximum at between 70° and 80°.

Besides these, as far as I am aware, the only instance is that announced by Professor Forbes* of elliptic polarization in the reflexion from mica when reduced to the particular state in which he used it for his experiments on heat.

On repeating the experiment I observed that it has its maximum at an incidence between 20° and 30°, and the direction of dislocation, 90°. But the films thus formed do not lose their crystalline structure or retarding property: it may therefore be doubtful how far the effect may be explicable in the ordinary way.

Decomposed Glass.

In some specimens of glass, whose surface is in a well-known peculiar state of decomposition, not only iridescent, but having a singularly metallic lustre, I found elliptic polarization, though none was perceptible in other specimens, however highly iridescent, which had not the metallic appearance. There are, however, anomalies with other metallic reflexion, for the maximum effect appears at *small* incidences (about 30° or 40°), and the direction of dislocation is 90°.

Minerals, &c.

Among a variety of metallic ores, I have found elliptic polarization produced only by a few having a decided metallic lustre. What proportion of metal may be necessary to give ellipticity, is an interesting question for future research. But one remarkable instance is that of *plumbago*, which gives a small though distinct ellipticity; while its composition is well known to be doubtful: but on the highest estimate it contains 95 of carbon to 5 of iron†.

In some ores exhibiting a natural iridescence, the results seem analogous to those about to be described in artificial surfaces of this kind.

* British Association, 1839, Sectional Proceedings, p. 6.

† Thomson's Chemistry, i. 396. 6th Ed.

Oxidation.

The common effect of oxidation is to reduce the elliptic into plane polarization. This is the case with the oxidation produced on copper, &c. by a drop of dilute acid, and with the dull tarnished surface of most metals after long exposure.

A transparent film on the surface of polished metal may diminish or destroy the ellipticity, obviously from its refraction causing the rays to fall on the metal beneath at too small an angle.

Mercury, when pure, gives a large elliptic polarization; and even when the surface is coated with the film of oxide which so readily forms upon it, the ellipticity remains unaltered: the surface of the oxide, however, has a sort of metallic appearance.

Daguerreotype Plates.

With one of these plates on which a picture had been formed, at incidences of 60° and 70°, I could perceive no difference in the degree of ellipticity, or direction of dislocation, between those parts of the surface which remained bright, and those which had been most powerfully acted upon.

Tempered Steel.

With reference to the same objects I tried plates of steel in its ordinary state, and in two stages of tempering, viz. the yellow or straw-coloured, and the blue. The former is well known to be that formed at the lowest heat. The film or state of surface thus produced occasions changes both in the amount and direction of the dislocation.

Dr. Thomson*, in describing the process of tempering, observes that it is a question whether the changes in colour be due to thin plates of an oxide simply, or whether there may not be different oxides produced in succession.

This last opinion agrees with the nature of my results, as well as with the absence of change of colour on altering the inclination. The results are as follows :—

Incidence.	Surface.	Polarization.	Centre.	Direction of dislocation.
70°	Steel, plain	Elliptic, large	....	0°
	Steel, tempered.			
	Yellow......	Elliptic, very small, or none	Dark...	0°
	Blue..........	Very small........	Dark...	90°

Coloured Films on Steel by Heat.

To examine the phenomena more precisely in their order of succession, I formed coloured films on plates of highly polished steel, about five inches square, by applying to the under side, at the centre, the flame of a spirit-lamp, when colours soon be-

* Chem. i. 386. 6th Ed.

gan to appear on the upper surface, and assumed the form of rings round the point of application of the heat.

Each tint appeared in succession, first at the centre, and thence extended itself. The first tints succeeded each other in the course of a few seconds; but the latter more slowly; until at length, after the heat had been continued for a considerable time, no further change took place.

The tints, proceeding in order from the outermost to the centre, may be described and grouped as follows:—

1. Reddish brown, crimson, deep purple, dark blue, light blue, faint yellow.
2. Faint red, light blue, pale reddish brown (at the centre).

The last two colours were very faint, and seemed covered with a sort of cloudy whiteness.

It is difficult to compare these tints with any part of NEWTON's scale: but I have here grouped them in two divisions which seem clearly marked by a periodicity, while in the last two tints a peculiar character appears to prevail.

The supposition of a change in the degree of oxidation before referred to, seems to accord with the peculiar appearance of the later tints, while the periodicity of the former agrees with the supposition of thin plates up to that point.

In the observed phenomena of ellipticity there appear distinctions corresponding to the *regular* orders of tints; for in passing them in succession under the apparatus, corresponding changes in the amount and direction of dislocation occur, as far as the red of the 2nd set; while in the remaining part, the ellipticity is greatly diminished, and no change in direction takes place.

The figures 1, 2, &c. distinguish successive parts of each coloured space at which the changes occur.

Incidence.	Surface.	Polarization.	Centre.	Direction of dislocation.
70°	Steel, plain	Elliptic, large.	. . . .	0°
	Films by heat.			
	1st Red	Elliptic, large	. . . .	0°
	Blue. 1	Plane.	Bright.	
	Blue. 2	Elliptic, large	. . . .	90°
	Yellow.	Plane.	Dark.	
	2nd Red	Elliptic, large	. . . .	0°
	Blue, &c.	Small	Dark . .	0°

Coloured Films on Copper by Heat.

I formed colours in exactly the same way on plates of copper of the same size. The tints here do not appear exactly the same as those on steel, though there is some general correspondence: they follow this order, commencing from the outermost.

1st. Red, purple, pale yellow, yellow.

2nd. Red, green, dull brown.

The last two tints have a sombre appearance, different from the metallic lustre of the others: this (as in the last case) may accord with the supposition of a different degree of oxidation.

Here also I find similar changes in the ellipticity through the first tints, but none in the last two.

Incidence.	Surface.	Polarization.	Centre.	Direction of dislocation.
70°	Copper, plain ..	Elliptic, large.	....	0°
	Films by heat.			
	1st Red	Elliptic, large	....	0°
	Purple........	Plane............	Bright.	
	Yellow.... 1	Elliptic, large	....	90°
	Yellow.... 2	Plane............	Dark.	
	2nd Red	Elliptic, large	....	0°
	Green, &c.	Small............	Dark ..	0°

NOBILI'S *Coloured Films.*

Besides furnishing me with several specimens of these films on steel plates, in which very brilliant tints were developed as far as the 3rd order, Dr. DAUBENY kindly caused other plates to be prepared in his laboratory, in order to trace the order of the effects produced.

In forming one of these, the process was continued longer than before, and thus a 4th order of very faint colours succeeded. In another instance the process was continued still longer, and colours were formed which went through the same series as before, but at the 4th order they became extremely dusky and obscure; and the 5th order was barely visible from increasing opacity. They followed one another in succession towards the circumference, where they were at length crowded together, forming a narrow fringe, within which the central space was of a deep brown or black, of a dull, opake, appearance; and when this had occurred, the galvanic action being kept up for some time afterwards, no further change took place.

It can hardly be doubted that the increasing dulness in the later orders of tints, and final opacity of the film, are due to some change in the nature of the deposit which is superinduced at this stage of the process.

On bringing the coloured parts of the plate successively under the apparatus, the changes in the rings were clearly marked through the three orders of tints; though they followed in very close succession, commencing upon the edge of the film; and in the passage through the bright-centred system the variations of colour were striking, and at first somewhat perplexing.

The following general results were derived from repeated observations with different plates compared together.

Incidence.	Surface.			Polarization.	Centre.	Direction of dislocation.
70°	Steel, plain			Elliptic large	....	0°
	NOBILI'S films.					
	First order. .	yellow	1	Elliptic, large	....	90
			2	Plane	Dark.	
		red. .	3	Elliptic, large	....	0
			4	Plane	Bright.	
	Second order	green	1	Elliptic, large	....	90
			2	Plane	Dark.	
		red . .	3	Elliptic, large	....	0
			4	Plane	Bright.	
	Third order	green	1	Elliptic, large	....	90
			2	Plane	Dark.	
		red . .	3	Elliptic, large	....	0
			4	Plane	Bright.	
	Fourth order	green		Elliptic, small	Dark.	0
		red		Elliptic, very small	Dark.	0
	Black			Elliptic, very small, or none	Dark.	0

Analytical Investigation.

Mr. AIRY's general formula is investigated as follows :—

In the usual notation of the undulatory theory, we suppose a vibration in a plane P, represented by

$$a \sin \frac{2\pi}{\lambda}(v t - x)$$

incident on a metallic surface, so that P is inclined 45° to the plane of reflexion R. Then (the vibration perpendicular to R being accelerated in phase by ϱ) the resolved parts are

$$\frac{a}{\sqrt{2}} \sin \frac{2\pi}{\lambda}(v t - x) \quad . \quad . \quad . \quad . \quad \text{in R.}$$

$$\frac{a}{\sqrt{2}} \sin \frac{2\pi}{\lambda}(v t - x + \varrho) \quad . \quad . \quad \text{perpendicular to R.}$$

Then for a plane Q in the crystallized plate inclined to R by an angle φ (omitting the constant coefficient) the vibration perpendicular to Q, giving the ordinary ray, O, will be

$$\sin\left(\frac{2\pi}{\lambda}(v t - x + \varrho)\right) \cos \varphi - \sin \frac{2\pi}{\lambda}(v t - x) \sin \varphi = \text{O},$$

and that in Q giving the extraordinary ray E will be

$$\sin\left(\frac{2\pi}{\lambda}(v t - x + \varrho)\right) \sin \varphi + \sin \frac{2\pi}{\lambda}(v t - x) \cos \varphi = \text{E}.$$

But on emergence from the crystallized plate the latter is accelerated by θ (depend-

ent on the thickness traversed), or it becomes

$$\sin\phi \sin\left(\frac{2\pi}{\lambda}(v t - x + \varrho) + \theta\right) + \cos\phi \sin\left(\frac{2\pi}{\lambda}(v t - x) + \theta\right) = \mathrm{E}'.$$

The parts remaining after analysation in a plane A perpendicular to P will then be,

$$\mathrm{O} \cos(45 - \phi) - \mathrm{E}' \sin(45 - \phi).$$

These upon expansion are at length reducible to the form

$$\mathrm{H} \sin\frac{2\pi}{\lambda}(v t - x) \quad + \mathrm{K} \cos\frac{2\pi}{\lambda}(v t - x),$$

whence, after reduction, we obtain

$$\mathrm{H}^2 + \mathrm{K}^2 = 1 - \sin^2 2\phi \cos\varrho - \cos 2\phi \sin\varrho \sin\theta - \cos^2 2\phi \cos\varrho \cos\theta,$$

which expresses the intensity of light at any part of the rings, assigned by ϕ and θ; and is susceptible of variations according to the value of ϱ, or the changes in retardation which may arise from differences in the nature of the metallic films, as in the following Table:—

Values of ϱ.	Expression for the intensity: θ given.					Nature of the rings.
	For ϕ in general.	$\phi = \begin{cases} 0 \\ 180^\circ. \end{cases}$	$\begin{cases} 45^\circ. \\ 225^\circ. \end{cases}$	$\begin{cases} 90^\circ. \\ 270^\circ. \end{cases}$	$\begin{cases} 135^\circ. \\ 315^\circ. \end{cases}$	
0	$1 - \sin^2 2\phi - \cos^2 2\phi \cos\theta$	$1 - \cos\theta$ . .	0	$1 - \cos\theta$ . .	0	Dark-centred, circular.
$\frac{\pi}{2}$	$1 - \cos 2\phi \sin\theta$	$1 - \sin\theta$ . .	1	$1 + \sin\theta$ . .	1	Dislocated (1).
π	$1 + \sin^2 2\phi + \cos^2 2\phi \cos\theta$	$1 + \cos\theta$ . .	2	$1 + \cos\theta$ . .	2	Bright-centred, circular.
$\frac{3\pi}{2}$	$1 + \cos 2\phi \sin\theta$	$1 + \sin\theta$ . .	1	$1 - \sin\theta$ . .	1	Dislocated opposite way to (1).
2π	$1 - \sin^2 2\phi - \cos^2 2\phi \cos\theta$	$1 - \cos\theta$ . .	0	$1 - \cos\theta$ . .	0	Dark-centred, circular.
&c.	&c.	&c.	&c.	&c.	&c.	&c.

These changes will accord with those observed through one order of tints, if the increase of ϱ from 0 to 2π correspond to an increment of one wave length, or if $\varrho = \frac{2\pi k}{\lambda}$ and k be made successively $= 0$, $\frac{\lambda}{4}$, $\frac{\lambda}{2}$, &c.

VI. *On the Laws of Individual Tides at Southampton and at Ipswich.* *By* G. B. Airy, *Esq., M.A., F.R.S., Astronomer Royal.*

Received February 16,—Read March 2, 1843.

WITH the view of verifying the reported peculiarity in the tides at Southampton, I had proposed in the month of February 1842 to proceed thither for the purpose of examining, with my own eyes, the rise and fall of the water during one or more tides. As soon, however, as my purpose was made known to Colonel Colby, R.E., Director of the Trigonometrical Survey, and to Lieutenant Yolland, R.E., the Resident Officer at the Ordnance Map Office, Southampton, I received from those gentlemen the offer of placing at my service, for these observations, non-commissioned officers and privates of the corps of Royal Sappers and Miners, as well as of preparing and fixing the vertical scale of feet and inches, and of keeping a watch upon the general accuracy of the observed times. I was extremely glad to avail myself of this offer, for I believe that a more intelligent and faithful body of men does not exist than the Sappers employed in the Trigonometrical Survey; and I knew well the advantage of employing, upon a tedious business like this, a set of regular-service men stationed on the spot.

A vertical scale of deal laths, upon which the divisions and figures were branded, was fixed near the end of the pier at Southampton, very near to the landing-stairs on the north side of the pier, so that the divisions could at all stages of the tide (with the assistance of a lantern at night) be easily read by a person standing on the stairs. The order of the graduations of the scale was increasing from the bottom upwards, and the zero of the scale was found, by levelling, to bear the following relation to certain fixed marks:—

[The mark in each case, except that of St. Paul's Church, is a horizontal cut, indicated by the point of an arrow. The arrow is on one side of the mark at Holyrood Church, and below each of the others.]

The zero of the scale is,

	feet.
Below a mark cut on the metal of the coat of arms on the north side of the pedestal of Chamberlayne's column, Watergate Quay	25·765
Below the ground at the same place	21·990
Below a mark cut in the stone jamb on the south side of the centre door of Holyrood Church	36·310
Below the floor of the portico	33·370

	feet.
Below a mark on the coin stone at the south-west angle of All Saints' Church	43·057
Below the flags of the footpath	37·657
Below a mark on the north side of the pedestal which supports the east lion at the north side of the Bar	50·514
Below the ground there	45·094
Below a mark in the bricks of the wall at the south-west side of the door of the toll-house, at the junction of the London and Salisbury roads	69·669
Below the ground there	67·219
Below the lower sill of the centre door of St. Paul's Church	77·814
Below the flag-stones	76·704
Below a mark on the south front of the west angle of the east wing of the buildings at the Ordnance Map Office	89·344
Below the ground there	87·449

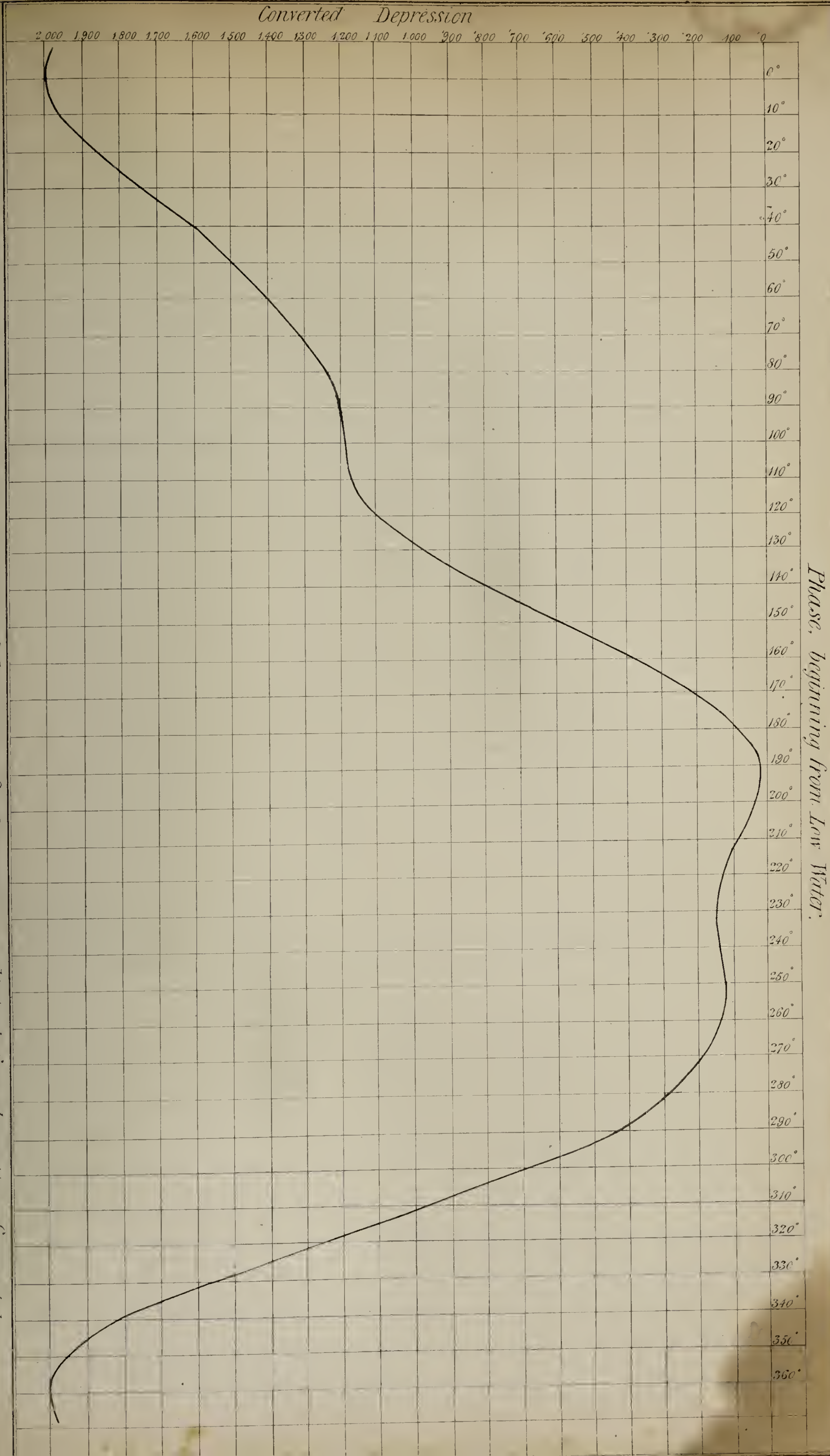
The height of the water upon this scale was observed at every five minutes, from February 23, $15^h\ 10^m$ (astronomical reckoning), to February 27, $6^h\ 20^m$. The watch by which the times were taken was a pocket chronometer belonging to Lieutenant YOLLAND, of which the error was small. The observations at February 24, $6^h\ 5^m$ and $6^h\ 10^m$, were omitted from inadvertence (darkness coming on before proper preparations were made); those of February 24, $6^h\ 35^m$ and $6^h\ 40^m$, were excluded from calculation, because the water was disturbed by a boat; and those of February 25, $2^h\ 0^m$, $2^h\ 5^m$, and $2^h\ 10^m$, because they were evidently irregular, although no reason was assigned for their irregularity.

When the seven complete tides embraced by these observations were laid down in graphical projection, each of them presented a curve similar in its general form to the extraordinary figure represented in the diagram, fig. 1. in Plate II.; four of the curves having three maxima of elevation in each tide. In the first two tides, the first maximum, as in the diagram fig. 1, was rather a stand-still in the rise than a rise and fall; and in the last tide (the highest of all), the first and third maxima were both of this character. In all the others, the three maxima to each tide were well marked.

On February 24, from 15^h to 17^h, the wind blew strong from W. and S.W. On February 25, from 18^h to 19^h, it blew a gale from S.W. and W. From February 25, 21^h, to February 26, 3^h, the wind was strong from S.W. and W. And from February 26, 20^h to 23^h, there was a strong W.S.W. wind. At other times the air was almost perfectly calm. These changes in the state of the atmosphere do not appear to have produced any sensible alteration in the character of the individual tides.

The epochs and magnitudes of the tides appear, however, to have been sensibly altered by these or other disturbing causes. Thus, if we examine the times and intervals of high water, they are as follows:—

Fig. 1.



Curve representing the law of rise and fall of the tide at Southampton, as obtained from observation of seven tides.
from 1842, Feb. 23rd. 15h. 25m. to Feb. 27th. 6h. 5m.

	h m		Interval h m
February 23. . .	22 5		
		. . Interval . .	12 30
24. . .	10 35		
		. . . .	12 20
24. . .	22 55		
		. . . .	12 30
25. . .	11 25		
		. . . .	12 10
25. . .	23 35		
		. . . .	12 25
26. . .	12 0		
		. . . .	12 15
27. . .	0 15		

These changes may possibly be due to diurnal tide.

The times and intervals of low water are the following:—

	h m		Interval h m
February 23. . .	15 25		
		. . Interval . .	12 30
24. . .	3 55		
		. . . .	12 5
24. . .	16 0		
		. . . .	12 30
25. . .	4 30		
		. . . .	13 20
25. . .	17 50		
		. . . .	11 25
26. . .	5 15		
		. . . .	12 25
26. . .	17 40		
		. . . .	12 25
27. . .	6 5		

These changes are utterly lawless.

The heights of high and low water, (taking for high water, in all cases, the second of the three maxima), and the ranges, are as follows:—

High Water. ft. in.	Low Water. ft. in.	Range. ft. in.
	4 $7\frac{3}{8}$	
	. . . .	12 $1\frac{1}{8}$
16 $8\frac{1}{2}$		
	. . . .	13 4
	3 $4\frac{1}{2}$	
	. . . .	13 $7\frac{1}{2}$
17 0		
	. . . .	14 $0\frac{1}{2}$
	2 $11\frac{1}{2}$	
	. . . .	14 0
16 $11\frac{1}{2}$		
	. . . .	14 10

High Water.		Low Water.		Range.	
ft.	in.	ft.	in.	ft.	in.
		2	$1\frac{1}{2}$		
				15	$2\frac{1}{4}$
17	$3\frac{3}{4}$				
				12	$9\frac{1}{2}$
		4	$6\frac{1}{4}$		
				13	$2\frac{1}{4}$
17	$8\frac{1}{2}$				
				15	9
		1	$11\frac{1}{2}$		
				15	$6\frac{1}{2}$
17	6				
				15	4
		2	2		
				16	5
18	7				
				16	3
		2	4		

The irregularities here are considerable, and, taken in conjunction with those of the times of low water, they seem to show that some powerful disturbing cause has affected the low water at February 25, $17^{h}\ 50^{m}$. Nevertheless, the tidal curves for the tides on both sides of that low water are undistinguishable, as viewed by the eye, from the rest; and in the grouping for the reductions, to be shortly explained, the numbers furnished by them do not differ sensibly from those given by the others.

Considering it then as established that the peculiarities in these tidal curves are the representatives of real peculiarities in the tides at Southampton (such as may always be expected in every individual tide of nearly the same magnitude as those observed on this occasion), and in no degree due to the accidental circumstances of weather; and considering also that these tides exhibit no certain trace of diurnal tide; I shall proceed to explain the method by which they have been reduced into mathematical form.

The method is, in many respects, similar to that which I used for the Deptford tides, in a paper published in the Philosophical Transactions for 1842. The first step was, to divide the whole series of observations into groups, each group representing one tide. This was done by taking the interval from low water to low water as one tide, and supposing it to correspond to 360° of *phase*, and converting the interval between every observation in that tide and its commencement into *phase*, by that proportion. The next step was to reduce the different observations of height to one uniform scale. This was done by assuming every range of tide, from high water to low water or from low water to high water, to be represented by 2, and converting the depression of the water at every observation below the high water of that tide into abstract number, by that proportion. In this manner every observation gave a phase expressed in degrees, and a converted depression expressed in abstract number. The next step was to collect from all the tides the phases between 0° and 5° and their

corresponding converted depressions, and to take their mean; then those between 5° and 10°; and so on. The phases thus obtained differed little from 2°·5, 7°·5, &c.; and the correction of converted depression for these small differences being easily found from the preceding and following numbers, the converted depressions for 2°·5, 7°·5, &c. were found. In this manner the following Table was formed:—

Corresponding phases and converted depressions in the Southampton Tides; the phase commencing with low water and increasing by 360° in one tide; and the depression being measured from high water, the whole range being called 2·000.

Phase.	Converted depression.	Phase.	Converted depression.	Phase.	Converted depression.	Phase.	Converted depression.
2°·5	1·996	92°·5	1·194	182°·5	0·064	272°·5	0·217
7·5	1·979	97·5	1·185	187·5	0·029	277·5	0·251
12·5	1·939	102·5	1·182	192·5	0·018	282·5	0·316
17·5	1·890	107·5	1·181	197·5	0·027	287·5	0·384
22·5	1·838	112·5	1·163	202·5	0·051	292·5	0·508
27·5	1·770	117·5	1·128	207·5	0·079	297·5	0·598
32·5	1·698	122·5	1·080	212·5	0·104	302·5	0·755
37·5	1·639	127·5	1·018	217·5	0·132	307·5	0·890
42·5	1·574	132·5	0·941	222·5	0·145	312·5	1·021
47·5	1·519	137·5	0·846	227·5	0·149	317·5	1·201
52·5	1·479	142·5	0·748	232·5	0·152	322·5	1·347
57·5	1·422	147·5	0·651	237·5	0·144	327·5	1·491
62·5	1·382	152·5	0·563	242·5	0·139	332·5	1·641
67·5	1·329	157·5	0·441	247·5	0·125	337·5	1·769
72·5	1·292	162·5	0·350	252·5	0·129	342·5	1·864
77·5	1·256	167·5	0·262	257·5	0·132	347·5	1·932
82·5	1·225	172·5	0·185	262·5	0·143	352·5	1·976
87·5	1·209	177·5	0·119	267·5	0·174	357·5	1·996

By means of these numbers the curve fig. 1 in Plate II. has been constructed.

To express these numbers in a mathematical form by means of a periodic function, it was assumed that the converted depression could be represented by the formula

$$\mathrm{A} + \mathrm{B}\,.\,\sin\text{ phase} + \mathrm{C}\,.\,\sin 2\text{ phase} + \mathrm{D}\,.\,\sin 3\text{ phase} + \mathrm{E}\,.\,\sin 4\text{ phase},$$
$$+\, b\,.\,\cos\text{ phase} + c\,.\,\cos 2\text{ phase} + d\,.\,\cos 3\text{ phase} + e\,.\,\cos 4\text{ phase}.$$

Then A is the mean of all the converted depressions. B is found by multiplying every converted depression by its value of sin phase, and dividing the sum of all the products by 36. b is found in the same way, using the values of cos phase as factors. C is found by using sin 2 phase as factor, &c. In this manner the following expression was found for the converted depression:—

$$0·900 + 0·469\,.\,\sin\text{ phase} - 0·085\,.\,\sin 2\text{ phase} - 0·057\,.\,\sin 3\text{ phase} - 0·017\,.\,\sin 4\text{ phase}$$
$$+\, 0·766\,.\,\cos\text{phase} + 0·174\,.\,\cos 2\text{ phase} + 0·182\,.\,\cos 3\text{phase} - 0·029\,.\,\cos 4\text{ phase};$$

or

$$0·900 + 0·898\,.\,\sin(\text{phase} + 58°\,30')$$
$$+\, 0·194\,.\,\sin(2\text{ phase} + 116°)$$
$$+\, 0·191\,.\,\sin(3\text{ phase} + 107°\,22')$$
$$-\, 0·034\,.\,\sin(4\text{ phase} + 59°\,43').$$

If we make phase $+ 58°·30' = p$, this becomes

$$0·900 + 0·898 . \sin p + 0·194 . \sin (2 p - 1°) + 0·191 . (\sin 3 p - 68° 8') - 0·034 . \sin (4 p - 174° 17').$$

The theory of waves, so far as it has yet gone, fails to explain the form of this expression. It is not reconcileable with that obtained on the supposition that the extent of vertical oscillation bears a sensible proportion to the depth, either when the length of the channel is indefinite, or when the channel is interrupted by a barrier*. The latter supposition is that which would seem to represent most exactly the circumstances of Southampton. It is to be remarked, however, that the investigations which I have cited suppose the section of the channel to be rectangular; a supposition which accords little with the state of the channel of the Southampton water, as shown by the extensive banks of mud discovered at low water there. The investigations also exclude friction.

The following consideration is suggested by the form of the expression at which we have arrived for the converted depression. If the tide were such as we suppose the sea-tide to be (that is, if its depression were expressed by a single sine or cosine), and if (as above) the *phase* were measured from low water, then the converted depression would be expressed by

$$A' + B' \cos \text{phase},$$

$$\text{or} \quad A' + B' \sin (\text{phase} + 90°).$$

From this we might be led to conceive that in all cases the argument of the principal term expressing the depression would be (phase + 90°), the *phase* being a quantity which commences from low water. But we find that it does in this instance depend on (phase + 58° 30′), or on (phase + 90° − 31° 30′), differing from the former by 31° 30′, which corresponds to one hour of time nearly. Now there seems to be no reason (except the convenience of mariners) why cotidal lines and speculations on the progress of the tide should be connected with high water rather than with low water, or any other phase of tide; the only thing with which, in a scientific view, they can properly be connected (as it appears to me), is the epoch of the argument of the principal term in the formula for depression. But, in the instance of Southampton, the time of actual low water differs from the time of greatest depression given by that term, by one hour; the times of high water differ about forty minutes. If then the peculiarity of the Southampton tide has been created in part by the shallowness of the English channel, and exists on the coast (we have no accurate information whether this is true or not), then the position of the cotidal line determined by the high water is erroneous, with reference to the views above mentioned, to a considerable extent.

Another consideration suggested by the same expression is this. The mean of the depressions at high-water and at low-water is 1·000. But the constant term which enters into the general formula for the depression is 0·900. Now I conceive the latter to be the number which truly represents the mean level of the water. In all cases,

* See Philosophical Transactions, 1842, p. 6.

therefore, in which the mean level of the sea in different places is compared, I conceive it is not sufficient to take the mean of high and low water, but it is necessary to express the depression by the formula A + B sin phase + *b* cos phase + C sin 2 phase + &c., and to adopt the constant A as determining the mean level. The difference, at Southampton, is about nine inches, by which quantity the *mean level*, as defined above, is higher than the mean of high and low waters.

The singularity of the results obtained at Southampton induced me to take measures for observing the tides in another estuary; and for this purpose I selected Ipswich as a good station. The positions of these places are not exactly similar: Southampton is *nearly* at the head of its gulf; Ipswich may be considered as being *absolutely* at the head of its gulf. The length of the Orwell does not differ materially from that of the Southampton water; and in depth, breadth, magnitude of tide, &c., it resembles it closely. Nevertheless, it will appear from the following results that the laws of the tides at these two places are extremely different.

An application made by me to Charles May, Esq. of Ipswich, was by him laid before the Dock Committee; and I received from that body a most courteous offer of every assistance which could be required for the observation of the tides. The immediate superintendence of the observations was undertaken by James Jones, Esq., Dockmaster; and to the talent and spirit with which this gentleman undertook the troublesome business, I am entirely indebted for the opportunity of presenting the Royal Society with trustworthy results.

The observations commenced on 1842, May 24, $23^h\ 40^m$ (astronomical reckoning), and finished on May 27, $3^h\ 35^m$; embracing four complete tides. The height of the water was observed at every five minutes. The zero of the scale is the Lock Sill. Great attention was given to the determination of time. No irregularity appears on the face of the observations except about May 25, 19^h, after a heavy squall from the S.S.E. with violent rain.

The times and intervals of high water are as follows:—

	h m		h m
May 25. . .	1 5		
		. . Interval .	12 15
25. . .	13 20		
		. . . . .	12 30
26. . .	1 50		
		. . . .	12 10
26. . .	14 0		
		. . . .	12 34
27. . .	2 34		

The times and intervals of low water are,—

	h m		h m
May 25. . .	6 55		
		. . Interval .	11 40
25. . .	18 35		
		. . . .	12 55
26. . .	7 30		
		. . . .	12 15
26. . .	19 45.		

And the heights and ranges are,—

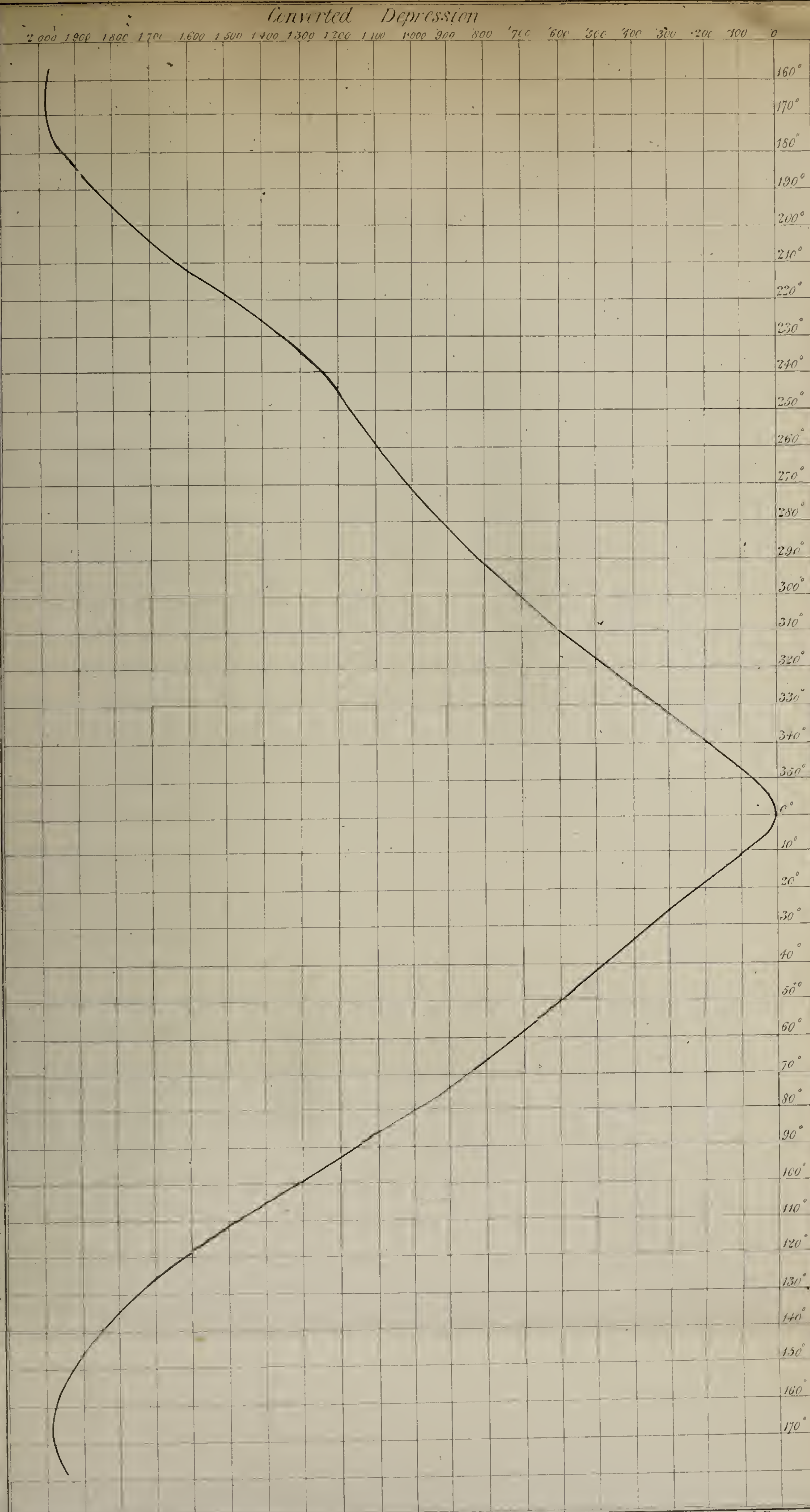
High Water. ft. in.	Low Water. ft. in.	Range. ft. in.
15 $10\frac{1}{4}$		
		12 $0\frac{3}{4}$
	3 $9\frac{1}{2}$	
		12 $0\frac{1}{2}$
15 10		
		11 $3\frac{1}{4}$
	4 $6\frac{3}{4}$	
		12 $3\frac{3}{4}$
16 $10\frac{1}{2}$		
		11 $11\frac{1}{2}$
	4 11	
		12 $0\frac{1}{2}$
16 $11\frac{1}{2}$		
		11 8
	5 $3\frac{1}{2}$	
		11 $0\frac{1}{4}$
16 $3\frac{3}{4}$		

The observations were reduced in exactly the same way as those made at Southampton, with this single difference, that the *phase* here began from high water (the first and last conspicuous phenomenon in these observations having been high water). And the values thus found for the converted depression are the following.

Corresponding phases and converted depressions in the Ipswich tides: the phase commencing with *high* water and increasing by 360° in one tide; and the depression being measured from high water, the whole range being called 2·000.

Phase.	Converted depression.	Phase.	Converted depression.	Phase.	Converted depression.	Phase.	Converted depression.
2°·5	0·012	92°·5	1·197	182°·5	1·894	272°·5	0·984
7·5	0·053	97·5	1·276	187·5	1·869	277·5	0·940
12·5	0·120	102·5	1·362	192·5	1·822	282·5	0·891
17·5	0·184	107·5	1·449	197·5	1·779	287·5	0·841
22·5	0·251	112·5	1·527	202·5	1·723	292·5	0·791
27·5	0·322	117·5	1·599	207·5	1·658	297·5	0·736
32·5	0·389	122·5	1·674	212·5	1·586	302·5	0·668
37·5	0·449	127·5	1·731	217·5	1·516	307·5	0·625
42·5	0·513	132·5	1·780	222·5	1·449	312·5	0·564
47·5	0·570	137·5	1·828	227·5	1·381	317·5	0·497
52·5	0·631	142·5	1·874	232·5	1·315	322·5	0·437
57·5	0·689	147·5	1·910	237·5	1·258	327·5	0·367
62·5	0·757	152·5	1·940	242·5	1·211	332·5	0·297
67·5	0·822	157·5	1·964	247·5	1·179	337·5	0·231
72·5	0·890	162·5	1·978	252·5	1·144	342·5	0·168
77·5	0·961	167·5	1·985	257·5	1·107	347·5	0·100
82·5	1·043	172·5	1·974	262·5	1·068	352·5	0·043
87·5	1·117	177·5	1·941	267·5	1·030	357·5	0·011

By means of these numbers the curve fig. 2 in Plate III. has been constructed. To make the phase commence at low water, its numerical value must be diminished by about 166°.



Curve representing the law of rise and fall of the tide at Ipswich, as obtained from observation of four tides. from 1842. May 25th 1h 5m to May 27th 2h 34m

J. Basire. Lith.

Treating these numbers in the same way as those for Southampton, and still conceiving the phase to commence at high water, we obtain the following formula for the converted depression:—

$$1{\cdot}055 + 0{\cdot}112 \,.\, \sin \text{phase} - 0{\cdot}096 \,.\, \sin 2\text{phase} + 0{\cdot}030 \,.\, \sin 3\text{phase} + 0{\cdot}012 \,.\, \sin 4\text{phase}$$
$$- 0{\cdot}851 \,.\, \cos \text{phase} - 0{\cdot}041 \,.\, \cos 2\text{phase} - 0{\cdot}076 \,.\, \cos 3\text{phase} - 0{\cdot}023 \,.\, \cos 4\text{phase};$$

or

$$1{\cdot}055 + 0{\cdot}858 \,.\, \sin(\text{phase} - 82^\circ\, 31') - 0{\cdot}104 \,.\, \sin(2\,\text{phase} + 22^\circ\, 59')$$
$$+ 0{\cdot}082 \,.\, \sin(3\,\text{phase} - 68^\circ\, 23') + 0{\cdot}025 \,.\, \sin(4\,\text{phase} - 63^\circ\, 2').$$

Let phase $- 82^\circ\, 31' = p$; this becomes

$$1{\cdot}055 + 0{\cdot}858 \,.\, \sin p + 0{\cdot}104 \,.\, \sin(2p + 8^\circ\, 1') - 0{\cdot}082 \,.\, \sin(3p - 0^\circ\, 50')$$
$$- 0{\cdot}025 \,.\, \sin(4p + 87^\circ\, 2').$$

The first three terms of this expression are extremely similar to those in the expression for the Southampton tide: the principal difference between the two expressions is in the fourth term, or that depending on $3\,p$. It is very remarkable that the algebraical difference between the formulæ for tides which are so strikingly different in general character, depends entirely on a term of the third order of the fraction expressing the proportion of the vertical oscillation to the depth of the water; an order to which (so far as I am aware) theory has reached only in one instance, namely that of a wave travelling along an unlimited canal, and then only on the restricted suppositions of rectangular section and absence of friction*. It is also worthy of remark, that the terms of the second order do not agree with those given by the restricted theory to which I have alluded, and that they differ materially from those given by the Deptford tides†. From a consideration of the discordance between the observations and the present state of theory in regard to the form of these terms, as well as from remarking the influence which they have upon cotidal lines and mean levels, I am inclined to fix upon the circumstances of waves in canals as more deserving of notice at the present time, both in theory and in observation, than almost any other branch of the theory of tides.

I take this opportunity of correcting an error in my paper on the Deptford tides‡. I have there stated, on the authority of Mr. WHEWELL§, that the age of the tide as inferred from the heights is greater than its age as inferred from the times. This, however, is incorrect. The age inferred from the heights is, in every instance that has been properly examined, less than that inferred from the times||. I trust that, in a subject which is at first examination very confusing, it will be regarded as a venial fault to have erred in such company as that of Mr. WHEWELL.

In a theoretical view, this correction is very important. The cause assigned for the

* See Philosophical Transactions, 1842, p. 6, and Encyclopædia Metropolitana, *Tides and Waves*, Article 210.

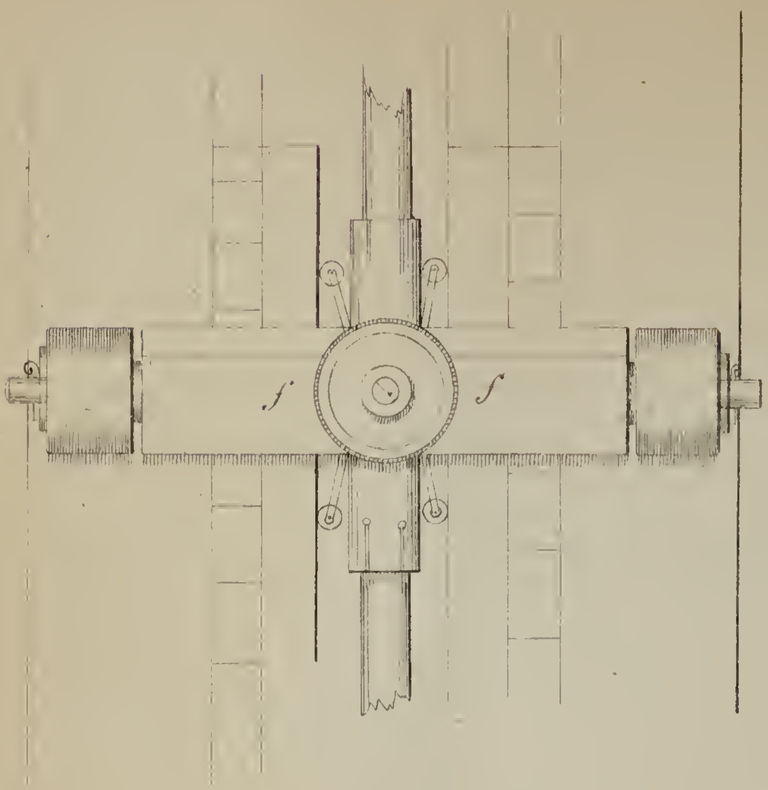
† Philosophical Transactions, 1842. ‡ Ibid. p. 8. § Ibid. 1838, p. 236.

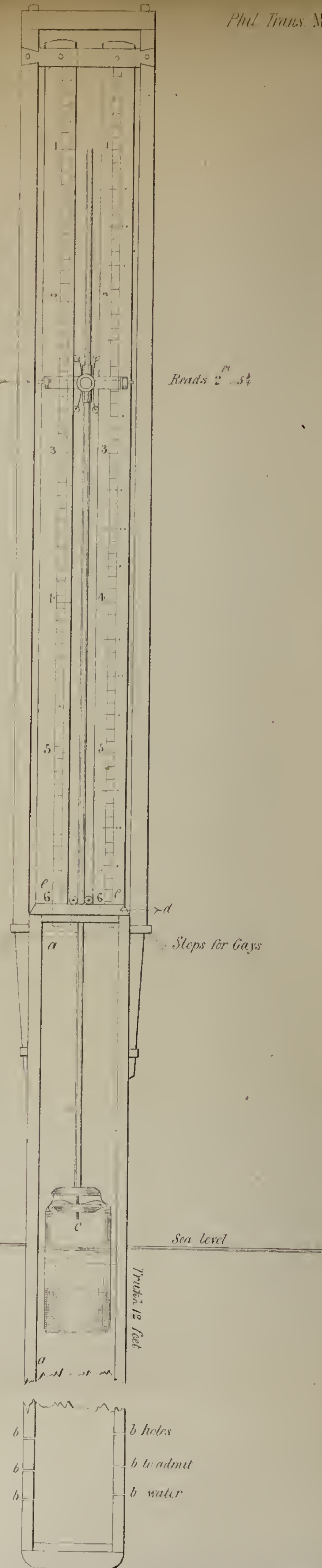
|| Encyclopædia Metropolitana, *Tides and Waves*, Article 543.

greater age inferred from the heights* is certain, as it is one given by observations which (here according with theory) show that the rise of tide occupies a shorter time at springs than at neaps. Some other cause must therefore exist, of such a kind as to make the tide later in springs than in neaps, and of such a magnitude as completely to overrule that already assigned. I conceive that this cause may be the increased range of the tide in horizontal extent up the river, at springs; by which the tide is changed from a gulf-tide to a continuous-canal-tide, which travels more slowly. But without more rigorous theory, I dare not pronounce upon this point.

Royal Observatory, Greenwich,
February 10*th*, 1843.

* Philosophical Transactions, 1842, p. 8.





J. Basire, Lith.

VII. *Tide Observations at Otaheite, or Tahiti.*

By Captain Sir E. Belcher, *R.N.* *Communicated by Captain* Beaufort, *R.N.*, *F.R.S.*, *&c.*

Received October 31, 1842,—Read February 16, 1843.

H. M. Ship Sulphur, Spithead,
July 22, 1842.

Sir,

With reference to that part of my instructions relating to noon high water at the Island of Otaheite, or Tahiti, I now transmit to you fair copies of the tide-journal registered at the island of Motouta, in the harbour of Papiete, as well as a short comparative series made at Point Venus.

The island of Motouta, the position before named, is the property of the Queen, and therefore free from intrusion or likelihood of disturbance. It is situated well within the reefs, upon a coral flat, and any wave tumbling over the reef would expend itself before reaching the island.

It is, at the same time, within the direct influence of the deep water channel, to seaward, but entirely protected by the reef. The swell does not enter by reason of the overlapping tongue of the northern reef, which, projecting westerly, receives and throws off the sea obliquely. The gauge was placed in ten feet of water, and the batten in four.

In order to prevent any confusion, by change of observers, and thus destroying the interest which a single individual would feel if entrusted with the sole execution of this interesting duty, I selected one of my old followers, Mr. McKinley Richardson, Mate, and placing him in entire charge of the island, furnished him with a tide-gauge of my own construction, as well as a tide-batten.

The tide-gauge was constructed as follows (Plate IV.):—A square wooden trunk of six inches aperture, *a a*, was closed at the bottom, but admitted water by small lateral holes, *b b*, six inches from the bottom. This was to prevent any sudden wave which might roll in from affecting the mean level.

Within this trunk floated a glass cylindrical jar *c*, five inches in diameter by eleven in height, and ballasted with sufficient small shot to half immerse it. It was rendered air-tight by means of the gauge-rod which screwed into an interior stuffed pad against the collar of the exterior.

The end of this rod was of brass, where it screwed into the float, but for ten feet above was of very light, tough cypress, half an inch in diameter.

At the summit of the trunk a cap was fitted, *d*, having three friction rollers, through

which the rod traversed freely. Above the trunk, secured to strong uprights, stepping into its exterior sides *e*, *e*, the graduated battens rose, having a clear space between them, and very neatly and *strongly* graduated with black divisions on a white ground.

The index had a clamp tube, through which the gauge-rod passed, *f*, when it was finally clamped at the first high water.

The index was a piece of machinery, *per se*, *f f*. It was furnished with fore, as well as back, friction rollers, on springs, amounting to eight, by which it maintained its position steadily, and kept the gauge-rod perpendicular. This machine had been well tested at Bow Island and its imperfections obviated.

This gauge was fixed upon the abrupt steep of the reef in ten feet water, and well ballasted by pigs of iron, on which it also rested. It was distant from the wall thirty yards, and easily read off by a telescope. It was registered during daylight (from 6 A.M. until 6 P.M.) *from the top*, so that the *least* number indicated high water, and *vice versâ*.

The tide-batten was lashed to the rocks (similarly ballasted) close to the wall of Motouta, in four feet water, and a thick plank enabled the observer to take the closest inspection. It was registered from the *bottom* by day as well as night, and by day at the same periods as the tide-gauge. The *greatest* number therefore indicates high water.

As it is almost impossible to determine the actual moment of high or low water, I had recourse to the method of equal altitudes, within two hours on each side; as the results of my observations on the coast of Lancashire, where the water was subject to a rise and fall of thirty-one feet, always coincided up to the latest half hour.

I have been thus minute in order to satisfy any sceptical minds bent on the maintenance of the *absolute noon period*, that the minutest attention was devoted to this duty, and the coincidence of the two observers, five miles asunder, will in some points be found to agree minutely.

It will be seen by reference to the mean tide-levels, subsequently reduced for each day (and *not contemplated* by the observers themselves), how strictly this duty was attended to, the range never exceeding *two inches* on either gauge or batten.

The position at Matavai was at the extremity of Point Venus, which was shielded in a great measure from the influence of the sea, by reefs similar to those at Papiete; but here we had merely tide-battens; the observations, however, were corroborated by repetitions within the rivulet, on a pole with crosses to mark the simultaneous levels, the more readily to deduce the moments of high and low water. These were watched for the last week by Mr. CHRISTOPHER GEORGE, second master, my general assistant in the observatory, and superintendent of the tide-journals.

These data (from the 22nd to the 27th) are comparable with those observed at Motouta.

By these documents it will be observed that there were two irregular moments of

high water during each twenty-four hours, and that their range was from 10 A.M. to 2^h 27^m P.M., or nearly 4^h 27^m by day, and 3^h 20^m by night. The influences of the sea or land breezes are not apparent. Indeed, if any such influence be admitted, it is decidedly at variance with the anticipated effect, as the night tides are *higher* with the land wind *off shore.*

With a *strong* land wind the height generally indicated the same as in calm. But the mean tide-levels before alluded to, distinctly indicate *an equable rise and fall.*

The night tides observed at Point Venus do not so exactly accord with those observed at Motouta.

I much regret that we had not an opportunity of observing the whole lunation; but I trust that sufficient has been advanced to satisfy you that no exertion was wanting in carrying through these intricate labours, and that even in their present form they may prove not altogether without interest.

I am Sir,

Your most obedient Servant,

EDWARD BELCHER, Captain.

Captain F. BEAUFORT, *R.N.*,
Hydrographer.

Abstract of Tide Observations.—Table I.

Otaheite. Island of Motouta. April 1840.

Date.	Mean time of High Water.	Mean time of Low Water.	Duration of Flood.	Duration of Ebb.	Height of Tide by Gauge.	Height of Tide by Batten.	Extreme Rise and Fall. Gauge.	Extreme Rise and Fall. Batten.	Mean Tide Level. Gauge.	Mean Tide Level. Batten.	Mean Tide Level. Diff.	Moon's Age.	Moon's Change.	Moon's Passage.	Diff. of Moon's Passage and High Water.	Weather, &c.
	h m	h m	ft. ins.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	h m	d h m	h m	h m	
☿ 8.	2 27 P.M.	.... 8 36	....	.... 6 9	3 10¼	1 6¾	0 1¾	0 4¾	3 9½	1 9	2 0½	5 9	☽ Q. 8 18 22	P.M. 5 21	2 54	Wind { from 9 0 A.M. to 4 0 P.M. S.W. 3 5 B.C. 4 P.M. 6 0 Calm. 0 B.C. 6 10 0 E.S.E. 3 B.C. 10 Mid. N.N.E. 2 B.C. At 4 P.M. the wind outside the reefs was apparently N.W.
♃ 9.	10 44 A.M. 10 00 P.M.	....	Tide irregular.		3 10¼ 3 4	1 8½ 2 1½	0 6½	0 5	3 7¼	1 11	1 8¼	6 9	....	6 20	3 40	Wind { from 0 0 to 9 0 A.M. N.N.E. 1 3 B.C. 9 0 Mid. S.W. 1 5 B.C.
♀ 10.	A.M. 10 45 .... 10 12	5 38 .... 4 36	.... 5 7 .... 5 36	7 38 .... 6 9	3 5 3 11½	2 2½ 1 7½	0 6½	0 7	3 8¼	1 11¼	1 9	7 9	....	P.M. 7 15	2 57	Wind { from 0 0 to 2 0 Calm 0 B.C. 2 0 8 30 S.E.&E. 2 B.C. 8 30 9 0 S.W. 2 9 0 Mid. S.E. to E. 2 4 B.C.
♄ 11.	A.M. 10 43 P.M. 11 40	6 5 .... 5 35	.... 4 38 .... 6 8	7 53 .... 6 5	4 1½ 3 5	1 5½ 2 4½	0 8½	0 11½	3 8½	1 9½	1 11	8 9	....	8 7	3 33	Wind { from 0 0 to 5 0 A.M. Calm 0 B.C. 5 0 5 P.M. East 1 4 B.C.N. 5 0 Mid. S.E. 2 B.C.
⊙ 12.	A.M. 10 0 .... 11 47	5 32 .... 5 25	.... 4 28 .... 6 12	5 52 .... 4 35	4 0 3 3½	2 5½ 1 4	0 8½	1 1½	3 8½	1 9	1 11½	9 9	....	8 54	2 53	Wind { from 0 0 to Noon N.N.E. 1 B.C. 1 Mid. Vble. Vble. 2 B.C.N.
☽ 13.	A.M. 11 20 .... 0 35 P.M.	6 0 .... 5 20	.... 5 42 .... 5 22	6 13 .... 5 26	3 2 4 3½	1 3 2 5½	1 1½	1 2½	3 9	1 10	1 11	10 9	....	9 37	2 58	Wind { from 0 0 A.M. to 9 0 A.M. Calm 0 B.C. 9 0 Mid. N.E. 1 2 B.C. R.P.M.
♂ 14.	.... 11 26 A.M. .... 11 42 P.M.	5 44 .... 6 20	.... 5 42 .... 5 22	5 9 .... 5 26	3 2 4 3½	2 5½ 1 3	1 1½	1 2½	3 9	1 10	1 11	11 9	....	10 22	0 53	Wind { from Easterly all day. 1 2 B.C. B.C.L.
☿ 15.	.... 11 50 A.M. .... 11 48 P.M.	6 2 .... 7 1	.... 5 48 .... 4 47	6 20 .... 4 49	4 3¼ 3 1	1 3 2 7½	1 2¼	1 4½	3 8¼	1 11¼	1 9	12 9	....	11 0	0 48	Wind { Easterly all day. 2 4 B.C. B.C.T.L. R.Q.C. R.O.Q.P.

TABLE I. (Continued.)

Otaheite. Island of Motouta. April 1842.

Date.	Mean time of High Water.	Mean time of Low Water.	Duration of Flood.	Duration of Ebb.	Height of Tide by Gauge.	Height of Tide by Batten.	Extreme Rise and Fall. Gauge.	Extreme Rise and Fall. Batten.	Mean Tide Level. Gauge.	Mean Tide Level. Batten.	Mean Tide Level. Diff.	Moon's Age.	Moon's Change.	Moon's Passage.	Diff. of Moon's Passage and High Water.	Weather, &c.
	h m	h m	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	h m	d h m	h m	h m	
♃ 16.	…… 11 52 A.M. ……	7 0 …… 6 40	…… 4 52 ……	7 18 …… 5 12	…… 4 3 3 0	…… 2 5 1 02	1 3	1 3	3 7½	1 10	1 9½	13 9	⊙ F. M. 16 7 55			Wind from 0 0 to 6 0 A.M. Easterly. 1 B. C. 6 0 — 8 0 Calm. 0 B. C. 8 0 — Mid. Easterly. 2 B. C.
♀ 17.	1 10 A.M. …… 0 25 P.M. ……	…… 6 48 …… 7 35	6 30 …… 5 37 ……	…… 5 38 …… 4 50	4 2 3 3	2 7 1 3½	0 11½	1 3½	3 8½	1 10¾	1 9¾	14 9	……	0 26	0 54	Wind from 0 0 A.M. to 9 0 A.M. Calm. 0 B. C. 9 — 1 30 Calm. 0 1 30 — 3 0 N.W. 2 3 B. C. 3 0 — Mid. Calm. 3 B. C.
♄ 18.	1 20 A.M. …… 1 10 P.M. ……	…… 6 38 …… 7 0	5 45 …… 6 32 ……	…… 5 18 …… 5 50	3 3 4 1½	2 5 1 4½	0 10½	1 0½	3 8¼	1 10¾	1 9¼	15 9	……	1 12	0 8	Wind from 0 0 A.M. to 6 0 A.M. E.S.E. 1 B. C. 6 0 — 0 0 Calm. 1 8 0 — 4 0 East. 3 4 0 — Mid. Calm. 0
⊙ 19.	1 18 A.M. …… 1 10 P.M. ……	…… 6 20 …… 8 54	6 18 …… 6 50 ……	…… 5 2 …… 7 44	4 0 3 4	2 4 1 3½	0 8	1 1½	3 8	1 11¼	1 8¾	16 9	……	1 58	0 40	Wind from 0 0 to 8 0 P.M. Calm. 0 B. C. 8 0 — Mid. Easterly. 1 2 B. C.
☽ 20.	1 35 A.M. …… 0 45 P.M. ……	…… 6 55 …… 7 17	4 41 …… 5 50 ……	…… 5 20 …… 6 32	4 1½ 3 5	2 3½ 1 3½	0 8½	0 12	3 9½	1 10	1 11½	17 9	……	2 49	……	Wind from 0 0 to 6 0 A.M. Easterly. 2 B. C. 6 0 — 10 0 Calm. 0 10 0 — 5 30 W.S.W. 1 4 B. C. 5 30 — 7 0 Calm. 0 B. C. 7 0 — Mid. Easterly. 1 B. C.
♂ 21.	1 37 A.M. …… 0 0	…… ……	Tide irregular, flowing and ebbing at intervals of three hours.				0 10	0 6	3 9	1 10	1 11	18 9	……	……	3 40	Wind from 0 0 A.M. to Noon. Easterly. 2 B. C. Noon — 5 0 P.M. N.W. 2 3 B. C. 5 0 — 9 0 Calm. 0 B. C. 9 0 — Mid. S.E. 1 3 B. C.
☿ 22.	2 30 A.M. …… 4 20 P.M.	7 41 8 3 …… 9 15	…… …… 8 13 ……	…… 5 37 …… 4 55	4 0 3 7½ …… ……	…… …… 1 10 1 5½	…… 0 4½	0 5 0 4½	3 9½	1 8¼	2 1½	19 9	……	4 32		Wind from 0 0 A.M. to 6 0 A.M. S.E. 2 B. C. 6 0 — 9 0 P.M. Calm. 2 B. C. 9 0 — Mid. West. 3 B.C.V.

Table I. (Continued.)

Otaheite. Island of Motouta. April 1840.

Date.	Mean time of High Water.	Mean time of Low Water.	Duration of Flood.	Duration of Ebb.	Height of Tide by Gauge.	Height of Tide by Battten.	Extreme Rise and Fall. Gauge.	Extreme Rise and Fall. Batten.	Mean Tide Level. Gauge.	Mean Tide Level. Batten.	Mean Tide Level. Diff.	Moon's Age.	Moon's Change.	Moon's Passage.	Diff. of Moon's Passage and High Water.	Weather, &c.
	h m	h m	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	h m	d h m	h m	h m	
♃ 23.	2 30 P.M.	.... 7 0	Tide ebbing and flowing at irregular intervals.				0 1½	0 2½	3 9¾	1 8¾	2 1	20 9	....	5 22	....	Wind from 0 0 A.M. to 5 0 A.M. Easterly. 2 B.C. 5 0 — 8 0 Calm. 0 B.C. 8 0 — 4 30 P.M. W.N.W. 1 4 B.C. 4 30 — 8 0 Calm. 0 B.C. 8 0 — Mid. S.E. 5 B.C.
♀ 24.	.... 10 30 A.M. 12 0	4 0 .... 2 30	.... 6 30 .... 7 30	9 0 .... 4 0	3 10½ 3 9	1 9½ 1 6	0 1½	0 3½	3 9¾	1 10½	1 11¼	21 9	☽ L. Q. 24 11 47	6 12	....	Wind from East to South. Calm and Variable. 1 2 B. C.
♄ 25.	.... 10 15 A.M. 9 15	4 15 .... 3 30	.... 6 0 .... 5 45	4 15 .... 5 15	4 0 3 8	1 11 1 6	0 4	0 5	3 10	1 8½	2 1½	22 9	....	6 59	....	Wind from 0 0 A.M. to 7 30 A.M. S.E. 1 3 B. C. 7 30 — 9 0 E.N.E. 2 B. C. 9 0 — 4 0 P.M. N.W. 1 4 B. C. 4 0 — Mid. South. 2 5 B. C.
☉ 26.	.... 10 30 A.M. .... 10 0 P.M.	4 0 .... 4 15	.... 5 30 .... 5 45	6 45 .... 5 45	4 1½ 3 7½	2 0½ 1 4½	0 6	0 8	3 10½	1 8½	2 2	23 9	....	7 46	....	Wind from Midnight to 10 0 A.M. S.E. 2 B. C. 10 0 — 4 0 N.byE. 2 B. C. 4 0 — Mid. Calm and Variable.
☽ 27.	.... 11 0 A.M. .... 10 30 P.M.	5 10 .... 4 0	.... 4 50 .... 6 30	7 10 .... 5 0	4 3½ 3 7	2 3 1 3	0 8½	0 12	3 11¼	1 9	2 2½	24 9	....	....	....	Wind from Midnight to 2 0 Calm. 2 0 — 6 0 S.E. 1 B. C. 6 0 — 8 0 Calm. 8 0 — 2 0 N.E. 1 C. 2 0 — Mid. Calm.
♂ 28.	.... 11 00 A.M. .... 9 45 P.M.	5 15 .... 3 30	.... 5 45 .... 6 15	6 45 .... 4 30	4 2 3 6	2 2 1 3½	0 8	0 10½	3 9	1 8¾	2 1½	25 9	....	....	....	Wind from 0 0 to 4 0 E.by N. 3 B. C. 4 0 — 10 0 S.E. 3 B. C. 10 0 — Mid. N. by W. 2 B. C.
☿ 29.	.... 11 0 A.M.	5 15	.... 5 45	7 30	4 1 3 7½	1 5 1 11½	0 5½	0 6½	3 9¼	1 9	2 2¼	26 9	....	....	....	Wind from 0 0 to 4 0 N.by W. 2 B.C.V. 4 0 — 6 0 S.E.byE. 2 1 6 0 — Mid. Calm & Var. B. C.

Table I. (Continued.)

Otaheite. Island of Motouta. May 1840.

Date.	Mean time of High Water.	Mean time of Low Water.	Duration of Flood.	Duration of Ebb.	Height of Tide by Gauge.	Height of Tide by Batten.	Extreme Rise and Fall. Gauge.	Extreme Rise and Fall. Batten.	Mean Tide Level. Gauge.	Mean Tide Level. Batten.	Mean Tide Level. Diff.	Moon's Age.	Moon's Change.	Moon's Passage.	Diff. of Moon's Passage and High Water.	Weather, &c.
	h m	h m	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	h m	d h m	h m	h m	
May ♀ 1.	11 30 A.M.	.... 6 20	....	6 50	....	2 2 1 2½	....	0 11½	....	1 8¼	....	28·9	1 12 6	....	....	Wind { from h m 0 0 to h m 4 0 S.E. 2 B. C. 4 0 to 8 0 E.N.E. 4 C. C. 8 0 to 8 0 E.N.E. 4 or 5 8 0 to Mid. S.E. 3 B. C.
♄ 2.	0 49 A.M. 11 55	.... 6 30 .... 6 52	6 29 .... 5 25	.... 5 41 .... 6 57	....	2 3½ 1 3	....	1 0½	....	1 9¼	....	0·5	....	....	....	Wind { from 0 0 to 4 0 S.E. 3 B. C. 4 0 to 8 0 E.S.E. 2 B. C. V. 8 0 to Noon. S.W. to E. 2 3 B. C. Noon to Midnight. E.S.E. 3 B. C.
⊙ 3.	0 51 A.M. .... 0 24 P.M.	.... 6 49 .... 6 57	6 0 .... 5 35	.... 5 58 .... 6 33	....	2 3 1 3	....	1 0	....	1 9	....	1·5	....	....	....	Wind { from Midnight to 8 0 E.S.E. 3 B. C. 8 0 to Mid. East. 3 4 6 B. C. V.
☽ 4.	1 11 A.M. .... 1 16 P.M.	.... 7 37 .... 7 15	6 14 .... 5 39	.... 6 26 .... 5 59	....	2 3 1 5	....	0 10	....	1 10	....	2·5	....	....	....	Wind from Midnight to Mid., S.E. to East 2, 4, 6 B. C.
♂ 5.	0 45 A.M. .... 0 57 P.M.	.... 6 52 .... 8 30	5 30 .... 6 5	.... 6 7 .... 7 33	....	2 2 1 6	....	0 8	....	1 10	....	3·5	....	....	....	Wind from Midnight to Midnight, Easterly 5 B. C.
☿ 6.	2 27 A.M. .... 2 43 P.M.	.... 7 57 .... 8 22	5 57 .... 6 46	.... 5 30 .... 5 39	....	2 2 1 6	....	0 8	....	1 10	....	4·5	....	....	....	Wind from Midnight to Mid., E.N.E. to N.E. 0, 1, 2 B. C.
♃ 7.	Tide irregular.		....	....	....	....	....	....	....	....	....	....	....	....	....	Wind { from Midnight to Midnight. Easterly with Calms. 1, 2, 0 B. V.

Table II.

Otaheite. Point Venus. April 1840.

Date.	Mean time of		Duration of		Height of Tide by		Extreme Rise and Fall.		Mean Tide Level.			Moon's			Diff. of Moon's Passage and High Water.	Weather, &c.
	High Water.	Low Water.	Flood.	Ebb.	Gauge.	Batten.	Gauge.	Batten.	Gauge.	Batten.	Diff.	Age.	Change.	Passage.		
	h m	h m	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	h m	d h m	h m	h m	
☿ 22.	4 52 P.M.	9 3 .... 9 11	7 49	.... 5 12	....	4 0 3 7	....	0 5	3 9½	....	....	19 9	....	4 32	....	Wind E.S.E. throughout the day. 2 4 B. C.
♃ 23.	.... 6 3 P.M.	7 41 10 33	7 30	....	....	3 11 3 8½	....	0 2½	3 9¾	....	....	20 9	....	5 22	....	Wind from h m 6 0 A.M. to h m 10 38 S.E. 2 B. C. 10 38 0 30 Calm. 2 0 30 1 10 N.N.W. 3 B. C. 1 10 Mid. Calm. B. C.
♀ 24.	.... 10 12 A.M. .... 7 47 P.M.	6 0 .... 2 18	.... 4 12 .... 5 29	.... 4 6	....	3 11½ 3 8	....	0 3½	3 10¾	....	....	21 9	☽ L. Q. 24 11 47	6 12	....	Wind S.E. to E.S.E. throughout the day. 4 B. C.
♄ 25.	10 20 A.M. .... 9 50 P.M.	.... 4 54	.... 4 56	6 34	....	4 2 3 7	....	0 7	3 11½	....	....	22 9	....	6 59	....	Wind from 0 0 A.M. to 2 0 P.M. S.E. 1 B. 2 0 6 0 N.W. 3 B. C. 6 0 Mid. E.S.E. B. C.
☉ 26.	.... 10 52 A.M.	7 20 .... 5 4	.... 3 32	.... 5 12	....	4 2 3 7½	....	0 7½	3 10¾	....	....	23 9	....	7 46	....	Wind S.E. throughout the day. 2 B. C.
☽ 27.	10 51 A.M.	.... 4 58	....	.... 6 7	....	4 2½ 3 7½	....	0 7½	3 10¼	....	....	24 9	....	8 32	....	Wind from 0 0 A.M. to 10 0 E.S.E. 3 B. 10 0 11 0 Calm. 3 B. 11 0 Noon. Easterly. 2 Noon. 5 0 Northerly. 2 B. 5 0 Mid. S.E. 2 B.
♂ 28.	11 16 A.M.	.... 4 56	....	5 42	....	4 3½ 3 6	....	0 9½	3 10¾	....	....	25 9	....	....	....	Wind from 0 0 A.M. to 4 0 S.E. 4 B. C. 4 0 10 0 S.E. by S. 2 B. C. 10 0 Mid. N. by W. 2 B. C.
☿ 29.	.... 11 20 A.M. .... 9 36 P.M.	6 10 .... 5 16	.... 5 10 .... 4 20	.... 5 56	....	4 4 3 6	....	0 10	3 11	....	....	26 9	....	....	....	Wind from Midnight to 4 0 N. by W. 2 B. C. 4 0 8 0 S.E. 1 B.C.V. 8 0 Noon. N.E. 4 Noon. Mid. Calm.

Tide Observations.

Otaheite. Motouta Island. April 1840.

Date.	Moon's age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
☿ April 8.	5 9	9 15 A.M.	3 10¼	......	S.W.	3	b.c.	
		37	3 10¼	1 6¾				
		10 4	3 10	1 7½	S.W.	3–4	b.c.	
		19	3 10	1 8				
		11 05	3 10	1 8	S.W.	3–5	b.c.	
		20	3 10	1 8½				
		45	3 10	1 8½	S.W.	3–5	b.c.	
		Noon.	3 9½	1 9½				
		0 35 P.M.	3 9½	1 9	S.W.	3–5	b.c.	
		1 05	3 9¼	1 9½				
		40	3 8½	1 10	S.W.	4	b.c.m.	
		2 4	3 8½	1 11½				
		27	3 8½	1 11½	....	.....	....	High Water 2^h 24^m.
		3 00	3 8	1 11	S.W.	4	b.c.m.	
		16	3 8	1 11				
		30	3 8½	1 10		3		
		50	3 8½	1 9½	S.W.	2	b.c.m.	
		4 02	3 8½	1 9½				
		25	3 8½	1 10	Calm.	......	....	Breeze outside strong N.W.
		45	3 8½	1 10				
		5 5	3 8½	1 10	....	......	b.c.m.	
		25	3 8½	1 10				
		40	3 8½	1 10				
		50	3 9	1 9½				
		59	3 9	1 9½	E.S.E.	1	....	Land breeze.
		6 20	......	1 9		1		
		50	......	1 8½				
		7 20	......	1 8½				
		51	......	1 8				
		8 49	......	1 7½	E.S.E.	3	b.c.	
		9 12	......	1 8				
		37	......	1 8½		3	....	Low Water 8^h 36^m.
		10 00	......	1 8½				
		30	......	1 8½				
		11 00	......	1 8½	N.N.E.	2		
		26	......	1 8				
		55	......	1 9		2		
		0 25 A.M.	......	1 9	N.N.E.			
♃ 9.	......	1 00	......	1 8½	....	3	b.c.	
		20	......	1 9				
		50	......	1 9				
		2 26	......	1 9	....	......	....	Tide irregular.
		3 00	......	1 9				
		35	......	1 8½	....	2		
		4 10	......	1 9				
		35	......	1 9½				
		5 00	......	1 9½				
		32	......	1 9½	....	2		
		5 50	3 10	1 9½	N.N.E.	3	b.c.	
		6 11	10½	8½				
		26	10½	8½				
		44	9	10				
		52	3 10	1 9½	N.E.	2		

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♃ April 9.	......	7 4 A.M.	3 9½	1 9¼				
		10	9½	9				
		24	10	9½	E.N.E.	2		
		42	9½	10				
		8 00	8½	10½				
		20	8	10½	....	1		
		38	8	10½	E.N.E.	1		
		54	7	11½	Calm.			
		9 5	6½	11½				
		20	6½	11½	W.S.W.	2	b.c.	
		35	5½	2 00	S.W.	4		
		10 2	4	0½				
		20	4	1				
		30	4	1½	S.W.	4	b.c.	
		11 00	5	1½				
		15	5	0½	S.W.	4	b.c.	
		32	5	1	S.W.	5	b.c.	
		46	5½	0½	....	......	....	High Water 10h 44m.
		Noon.	5½	1 11½				
		0 46 P.M.	5½	11½	S.W.	4	b.c.	
		44	5	11½				
		1 2	5	11				
		10	5	11				
		34	5½	11½				
		2 00	6	11½				
		28	6	2 0½	S.W.	3	b.c.	
		44	6	0½				
		3 5	6	1 0½	S.W.	2	b.c.	
		20	6	11½				
		40	5	2 1				
		55	4	2				
		4 4	4	0½	....	......	....	Tide irregular.
		17	4	0				
		40	5	1				
		50	5	1				
		5 2	5	2	S.W.	1	b.c.	
		40	5	1½				
		6 00	3 5	2				
		22	......	1				
		7 4	......	0				
		30	......	0				
		8 2	......	1 11½				
		14	......	11				
		40	......	2 0				
		9 5	......	0½	S.W.	2	b.c.	
		25	......	0½				
		10 0	......	0½	....	......	....	High Water 10h 00m.
		29	......	0½				
		52	......	0½				
		11 22	......	0				
		50	......	0				
		0 2 A.M.	......	2 0				
♀ 10.	......	10	......	1 11				
		1 20	......	10½	Calm.	......	b.c.	
		56	......	11	S.E.	2		

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♀ Ap. 10.	......	2 1 A.M.	......	1 11½				
		30	......	11				
		3 0	......	10½				
		27	......	10½				
		4 5	......	10½	S.E.	3		
		19	......	10½				
		35	......	10				
		5 5	......	9½				
		29	......	9	....	......	....	Low Water 5ʰ 38ᵐ.
		52	......	9	....	2		
		6 10	......	9½	....	1		
		28	......	9½	....	1		
		44	3 5	10½	E.	2	b.c.	
		7 4	5½	11				
		10	7	11				
		30	7	11½				
		45	7	11½				
		8 5	7½	11½				
		15	7½	2 0½	S.W.	1	b.c.	
		30	7½	0½				
		39	7	0½				
		9 2	6½	0½	Calm.	......	b.c.	
		25	6	1	N.E.	1	b.c.	
		40	6	0½				
		10 0	6	0½	....	4		
		20	5	1				
		40	5	2½				
		11 0	5	2	....	......	....	High Water 10ʰ 45ᵐ.
		20	6	1½				
		32	6	1				
		0 6 P.M.	6½	1 11				
		32	6½	11½				
		52	7	11				
		1 0	8	10				
		15	8½	9½	N.E.	4	b.c.	
		25	9	9				
		1 40	3 9½	1 8½				
		49	10	8½				
		2 0	10	8½	N.E.	4	b.c.	
		18	10	8				
		30	10	8				
		44	10	8½				
		55	10½	8				
		3 2	10½	8½				
		25	10½	8½				
		40	10½	8½				
		59	10	8½				
		4 10	11	8				
		40	11	7½	....	......	....	Low Water 4ʰ 36ᵐ.
		54	11½	8½				
		5 8	11½	8				
		22	11	8½	E.	2	b.c.	
		40	10½	9				
		50	10½	9	Calm.			
		6 2	3 10½	9				
		25	......	1 9				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♀ Ap. 10.	......	6 50 P.M.	......	1 10				
		7 20	......	9				
		40	......	10				
		8 2	......	10				
		28	......	11½	S.E.	1	b.c.	
		9 0	......	2 1½				
		30	......	2	Calm.			
		10 3	......	2	....	......	....	High Water 10^h 3^m.
		30	......	2				
		11 1	......	2				
		20	......	1½	E.	1	b.c.	
		32	......	1				
		46	......	0½				
		0 0	......	2 0	Calm.			
♄ 11.	......	0 14 A.M.	......	0½				
		34	......	1				
		52	......	1½				
		1 19	......	1				
		40	......	0½				
		2 4	......	1 11½	....	1		
		22	......	9½	....	1		
		49	......	8¼	....	1		
		3 14	......	7½				
		34	......	6½				
		48	......	6½				
		4 2	......	6½	Calm.			
		18	......	6½				
		35	......	6½	E.			
		5 00	......	1 6				
		25	......	6				
		6 00	......	5½				
		10	4 0	5½	....	......	....	Low Water 6^h 5^m.
		30	3 11½	7				
		50	11	7				
		7 2	10	8				
		14	10	8½				
		40	9	8½				
		50	8	9				
		8 2	8	10	E.	1	b.c.	
		16	8	11½				
		50	7½	2 0½	....	4		
		9 0	6	0				
		20	6	0½				
		37	6	0½				
		50	6	0½				
		10 0	5	1				
		23	5	1				
		42	5	2				
		11 5	5	1½	....	......	....	High Water 10^h 43^m.
		20	6½	1				
		32	6	1				
		40	5½	1½				
		Noon.	6	2 1	E.	3	b.c.	
		0 20 P.M.	6	0½				
		40	3 7	0				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♄ Ap. 11.	......	1 0 P.M.	3 8	1 10½				
		30	10	10½				
		55	10½	9½	....	3	b.c.v.	
		2 55	11	7				
		3 10	4 0	6½				
		4 10	1	5½				
		50	1½	5	....	2	b.c.v.	
		5 30	1½	5				
		55	1½	5	S.E.	2	c.v.	
		6 10	0½	6½	....	......	....	Low Water 5h 35m.
		40	......	7				
		7 10	......	8½				
		40	......	10				
		8 15	......	11	....	2	b.c.	
		50	......	2 1				
		9 25	......	1½				
		55	......	2				
		10 25	......	3				
		11 0	......	4				
		40	......	4½				
		0 20 A.M.	......	4	....	2	b.c.	High Water 11h 40m.
		1 00	......	2 2				
☉ 12.	......	20	......	0½				
		50	......	1 11				
		2 30	......	10				
		3 10	......	8				
		40	......	6½				
		4 20	......	5½				
		5 10	......	4				
		32	4 0	4	....	......	....	Low Water 5h 32m.
		50	4 0	4				
		6 5	4 0	5				
		35	1	5				
		7 00	1	6				
		25	1	6				
		40	4 0	7				
		8 0	3 10	8				
		10	9½	9				
		32	9	10				
		9 0	7	2 0				
		25	6	0½				
		40	6	1				
		10 1	5½	2				
		20	5	1				
		11 0	6	1				
		Noon.	5½	0½	....	......	....	High Water 10h 00m.
		0 30 P.M.	5	0½				
		15	5½	0½				
		1 40	6½	1 11½				
		2 20	7½	10½				
		50	8	10				
		3 2	9	10				
		30	4	6				
		5 0	4	5				
		25	3½	4½	....	......	....	Low Water 5h 25m.
		50	3 1	6				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
☉Ap. 12.	......	6 20 P.M.	......	1 6				
		35	......	8				
		7 5	......	9				
		20	......	10				
		8 5	......	11	N.E.	2	b.c.	
		35	......	2 2				
		9 10	......	2½				
		40	......	3				
		10 15	......	4½				
		45	......	5				
		11 9	......	5				
		45	......	5½	Calm.	1	b.c.	High Water 11^{h} 47^{m}.
		0 40 A.M.	......	2 5				
☽ 13.	......	1 20	......	3½				
		55	......	1½				
		3 5	......	0½				
		30	......	1 11	Calm.	......	b.c.	
		50	......	10				
		5 0	......	9				
		20	......	8				
		40	4 2	7				
		6 0	2	5	N.E.	2	....	Low Water 6^{h} 0^{m}.
		20	1	6				
		40	0	6				
		7 0	0	7				
		16	3 11	8				
		40	11	7½				
		8 1	10½	8	Calm.			
		20	9	9				
		40	8	11				
		9 0	6	2 0				
		20	5	1	N.E.	1	b.c.	
		40	4	1				
		10 1	5	1				
		34	5½	1				
		46	4	2				
		11 4	4	2				
		18	4	2½				
		Noon.	4	2	Calm.	......	b.c.	High Water 11^{h} 20^{m}.
		0 26 P.M.	5	2				
		40	5	1½				
		1 0	6	1	N.E.	1	b.c.	
		20	7	1 11				
		2 0	9	8				
		16	10	8	Calm.	......	b.c.	
		30	11	8				
		3 0	11	8				
		10	11½	7	N.E.	2	b.c.	
		30	11½	6½				
		4 0	11½	6				
		25	11	5½				
		30	4 0	5				
		46	2	4				
		5 0	3	3				
		35	3	3	....	1	b.c.	Low Water 5^{h} 20^{m}.
		6 0	4	3½				

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
☽ Ap. 13.	......	35 P.M.	......	1 4½	....	......	R.	
		6 59	......	5				
		7 14	......	5½				
		30	......	6½	....	......	Strong breeze off the land.	
		45	......	7½				
		8 5	......	1 8½				
		30	......	11				
		55	......	11½				
		9 30	......	2 0				
		10 10	......	2				
		25	......	3½				
		55	......	4½				
		11 20	......	5				
		50	......	5				
		0 35 A.M.	......	2 5½	E.	2	b.c.	High Water 0^h 35^m.
♂ 14.	......	1 10	......	5				
		50	......	5				
		2 20	......	2				
		3 0	......	1 10				
		30	......	8				
		4 10	......	7				
		50	......	6½				
		5 2	......	4	E.	2	b.c.	
		26	......	4				
		6 2	4 2	4	....	......	....	Low Water 5^h 44^m.
		26	2	4				
		7 20	0	5				
		55	2	6				
		8 20	3 11	8				
		9 0	9	10				
		26	7	2 1				
		40	4	1				
		10 1	4	2	E.	2	b.c.	
		17	3	3				
		40	3	4				
		11 0	2	4				
		12	2	5				
		22	2	5	....	......	....	High Water 11^h 26^m.
		40	2	5				
		Noon.	2	4				
		0 20 P.M.	2	3				
		40	3	3				
		1 0	3	3	....	1	b.c.	
		20	4	2				
		30	5	1				
		50	6	0				
		2 2	7	1 11½				
		3 2	9	10				
		20	10	8½				
		40	11	7				
		4 1	11¾	6	....	......	b.c.	
		27	4 1	4				
		40	2	4				
		5 0	4 2	1 3½	E.	1	b.c.	
		20	3	3½				

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♂ Ap. 14.	......	5 40 P.M.	4 3	1 3½				
		6 0	......	3	....	......	....	Low Water 6h 20m.
		40	......	3				
		7 0	......	4	E.	1	b.c.l.	
		20	......	5				
		45	......	6				
		8 10	......	7½	....	1	b.c.	
		20	......	7½				
		40	......	10				
		9 10	......	11½				
		37	......	2 1½	Calm.	......	b.c.l.	
		10 10	......	3½				
		11 0	......	5				
		30	......	5½	E.	2	b.c.	
		0 20 A.M.	......	5½	....	......	....	High Water 11h 42m.
		1 40	......	2 4				
☿ 15.	......	2 0	......	3				
		18	......	2				
		3 0	......	2				
		30	......	2				
		4 5	......	1 10½				
		30	......	8				
		5 0	......	4	E.	2	b.c.	
		20	......	4				
		40	......	3				
		6 0	4 2	3				
		30	3¼	3	E.	4	b.c.	
		7 4	2	4	....	......	....	Low Water 6h 2m.
		30	1	5				
		8 10	0	6				
		20	3 11	8				
		9 0	8	9				
		14	7½	10				
		38	6	10	E.	4	b.c.	
		10 1	5½	2 0				
		26	5	0				
		40	4	1				
		11 1	3	2½				
		16	2	4				
		40	1	5				
		50	1½	6				
		Noon.	1	5½	....	4	....	High Water 11h 50m.
		0 16 P.M.	1	3				
		38	1½	3				
		1 6	2	3				
		35	2½	2½				
		2 0	3 1	2 2	E.	......	b.c.t.l.	
		16	6*	1	....	......	....	* Gauge went down suddenly 5 inches.
		35	7	1 11½				
		3 0	8	10				
		16	9	9				
		32	10	8				
		45	11	7	E.	3	b.c.t.l.	Heavy rain; lightning over Island of Eimeo.
		4 0	4 0	6				
		16	1	5				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
☿ Ap. 15.	......	4 40 P.M.	4 1	1 4½				
		5 0	1	4½	....	2	r.q.c.	
		10	1	5				
		26	2	4½				
		6 0	2	4½	W.N.W.	......	l.q.c.p.	Heavy rain.
		20	......	4½				
		40	......	4				
		7 16	......	1 3	....	......	....	Low Water 7^h 1^m.
		37	......	5				
		40	......	7½				
		8 10	......	10				
		50	......	2 1				
		9 15	......	2½				
		40	......	3½				
		10 15	......	4½				
		48	......	6				
		11 35	......	7½				
		45	......	7½	....	......	....	High Water 11^h 48^m.
		0 15 A.M.	......	2 7	E.	1	b.c.l.	
♃ 16.	......	40	......	5½				
		1 15	......	4				
		50	......	2½				
		2 25	......	1				
		3 0	......	1 11				
		30	......	10				
		45	......	9½				
		4 0	......	8½				
		55	......	5½				
		6 0	......	3½				
		15	4 3	3½				
		30	3	3½	Calm.			
		7 0	3	3	....	.....	....	Low Water 7^h 0^m.
		25	2	4				
		45	2½	4½				
		8 0	2	5½				
		20	1	6				
		32	0	7				
		46	3 10	9	Calm.			
		9 0	3 9	1 10½				
		20	8	2 0½				
		40	7	1				
		10 0	5	2				
		22	5	2				
		46	3	4				
		11 20	2	5				
		40	2	5				
		Noon.	2	5				
		0 30 P.M.	1½	5	Calm.	......	....	High Water 11^h 52^m.
		40	2	4				
		1 0	2	4				
		18	1	3				
		40	0	2				
		2 0	2	2½				
		30	4	0				
		3 0	7	1 11				

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♃ Ap. 16.	......	3 11 P.M.	3 8	1 10				
		32	9	9				
		4 0	10	9				
		20	9	8	Calm.	......	b.c.	
		40	4 0	6				
		5 10	3 11½	5				
		25	4 1	4				
		39	2	4				
		46	2	4				
		6 0	3	3½				
		9	2	4	Calm.	......	b.c.	
		20	2	3				
		40	......	2	....	......	....	Low Water 6^h 40^m.
		7 12	......	4				
		35	......	4½				
		8 0	......	6				
		11	3 11½	6	E.	2	b.c.	Land breeze.
		20	......	6½				
		40	......	7	....	1	b.c.	
		9 0	......	7				
		20	......	9				
		44	......	11	E.	1	b.c.	
		10 0	3 7	11				
		20	......	2 0½				
		40	......	2				
		50	......	3				
		11 0	......	4				
		16	......	4				
		30	......	4				
		36	......	5				
		49	......	5	E.	3	b.c.	
		Midnight.	......	6				
♀ 17.	......	0 10 A.M.	......	2 6½				
		30	......	6½				
		1 0	......	7	....	......	....	High Water 1^h 10^m.
		20	......	6½				
		45	......	5½				
		55	......	4				
		2 15	......	3½				
		45	......	2½				
		3 5	......	1				
		25	......	1 11				
		50	......	9½				
		4 25	......	8½				
		5 5	......	7½				
		30	......	5½				
		6 15	......	4½				
		40	4 2	4½	Calm.	......	b.c.	
		7 00	2	4½	....	......	....	Low Water 6^h 48^m.
		18	2¼	4½				
		40	2	5				
		8 00	1	6				
		30	0½	6				
		9 00	3 11	7				
		25	10	8				
		40	8	10	W.	1	b.c.	

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♀ Ap. 17.	......	9 47 A.M.	3 8	1 11				
		10 0	7	$11\frac{1}{2}$				
		16	7	$11\frac{1}{2}$				
		30	6	2 $0\frac{1}{2}$	Calm.			
		40	6	$0\frac{1}{2}$				
		11 0	5	1	E.	1	b.c.	
		30	3	2				
		40	3	2				
		50	3	3				
		Noon.	3	3	S.W.	1	b.c.	
		0 10 P.M.	$3\frac{1}{4}$	$3\frac{1}{2}$				
		22	$3\frac{1}{2}$	4				
		40	3	$3\frac{1}{2}$	Calm.	......	....	High Water 0^h 25^m.
		1 0	3	4				
		20	3	3				
		35	$3\frac{1}{4}$	$3\frac{1}{2}$	N.W.	2	b.c.	
		45	4	$2\frac{1}{2}$				
		50	4	$2\frac{1}{2}$	W. by S.	3	b.c.	
		2 0	4	$2\frac{1}{2}$				
		10	4	$2\frac{1}{2}$	W.	2	b.c.	
		40	5	$0\frac{1}{2}$				
		50	6	0				
		3 0	6	$0\frac{1}{2}$	W.N.W.	2		
		20	$6\frac{1}{2}$	0				
		35	$7\frac{1}{2}$	1 11				
		50	3 9	1 10				
		4 0	9	9				
		20	10	8				
		32	11	7				
		46	4 0	7				
		5 2	0	$6\frac{1}{2}$	Calm.			
		10	0	$6\frac{1}{2}$				
		30	1	5				
		42	$1\frac{1}{2}$	5				
		50	2	$5\frac{1}{2}$				
		6 0	2	$5\frac{1}{2}$				
		30	......	4				
		40	......	4				
		7 0	......	4	E.	2	b.c.	
		15	......	$3\frac{1}{2}$				
		31	......	$3\frac{1}{2}$				
		42	......	$3\frac{1}{2}$	Calm.	......	....	Low Water 7^h 35^m.
		56	......	$3\frac{1}{2}$				
		8 5	4 $2\frac{1}{4}$	$4\frac{1}{2}$				
		22	......	4				
		9 0	......	$5\frac{1}{2}$	E.S.E.	2	b.c.	
		30	......	8				
		10 0	3 8	$10\frac{1}{2}$				
		25	......	11				
		55	......	2 0				
		11 25	......	$1\frac{1}{2}$				
		55	......	$2\frac{1}{2}$				
		45	......	3				
		Midnight.	......	$3\frac{1}{2}$	E.S.E.	3	b.c.	
♄ Ap. 18.	......	0 30 A.M.	......	2 $3\frac{1}{2}$				

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♃ Ap. 18.	......	1 0 A.M.	......	2 5				
		20	......	5	....	......	....	High Water 1^h 20^m.
		40	......	5				
		2 5	......	4				
		30	......	$2\frac{1}{2}$				
		50	......	$1\frac{1}{2}$				
		3 20	......	0				
		40	......	1 11				
		4 0	......	10				
		40	......	9				
		5 0	......	8				
		30	......	7				
		6 0	4 $0\frac{1}{2}$	6				
		20	$0\frac{1}{2}$	6				
		30	1	$5\frac{1}{2}$				
		40	1	$5\frac{1}{2}$	....	......	....	Low Water 6^h 38^m.
		7 0	1	$5\frac{1}{2}$				
		20	1	6				
		40	4 1	1 6				
		8 0	1	6				
		7	1	6				
		45	1	$6\frac{1}{4}$				
		9 5	3 11	7				
		29	10	8				
		40	$9\frac{1}{2}$	9				
		10 5	11	10				
		30	8	11				
		50	6	2 0				
		11 0	5	1				
		30	5	1				
		40	$4\frac{1}{2}$	$1\frac{1}{2}$				
		Noon.	$3\frac{1}{2}$	$2\frac{1}{2}$				
		0 15 P.M.	3	3				
		30	3	4				
		40	3	4				
		50	3	4				
		1 0	3	5				
		20	$2\frac{1}{2}$	$4\frac{1}{2}$	Calm.	......	b.c.	
		30	3	4				
		2 5	$2\frac{1}{2}$	$3\frac{1}{2}$				
		25	$2\frac{1}{2}$	3				
		3 2	$2\frac{1}{2}$	3				
		30	5	2				
		45	7	$0\frac{1}{2}$	S.W.	3	P.R.	
		4 0	9	1 $10\frac{1}{2}$				
		20	$10\frac{1}{2}$	9				
		5 0	4 0	$7\frac{1}{2}$				
		20	1	6				
		6 0	$1\frac{1}{2}$	$4\frac{1}{2}$				
		20	......	$4\frac{1}{2}$				
		40	......	$4\frac{1}{2}$				
		7 20	......	$4\frac{1}{2}$				
		50	......	$4\frac{1}{2}$				
		8 20	......	$4\frac{1}{2}$				
		50	......	5				
		9 30	......	$6\frac{1}{2}$				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♄ Ap. 18.	......	10 10 P.M.	......	1 8				
		40	......	9½				
		11 10	......	11				
		30	......	2 0				
		Midnight.	......	1½				
		0 40 A.M.	......	2 3	S.	2	b.c.	
⊙ 19.	......	1 5	......	4				
		30	......	4	....	......	....	High Water 1^h 18^m.
		2 0	......	3				
		40	......	1½				
		3 20	......	2 0½				
		40	......	1 11½				
		4 0	......	11				
		50	......	10				
		5 0	......	9½				
		30	......	9				
		40	......	8				
		6 0	......	7				
		10	......	6				
		20	4 0	3½	....	......	....	Low Water.
		40	1	1 5½				
		7 0	1	5½	Calm.	......	b.c.	
		10	1	5½				
		30	1	5½				
		40	1	5½				
		8 0	1½	5½				
		30	1	7	S.W.	1	b.c.	
		45	0	6½				
		9 5	1	6½	Calm.			
		20	0	7				
		30	0	7				
		45	3 11½	7				
		10 0	11	7	N.E.	2	b.c.	
		20	10½	8				
		40	10	9				
		50	9	10				
		11 0	9	11½	W.N.W.	2–4	b.c.	
		20	7	12½				
		40	6½	2 0½				
		12 0	6	1½	....	4	b.c.	
		0 20 P.M.	5	2				
		30	5½	2½	W.	4	b.c.	
		40	5	2½				
		50	5	2½	Calm.			
		55	4½	2½				
		1 0	4	3	N.W.	3	b.c.	
		15	4	3				
		31	4	2½	....	......	....	High Water 1^h 10^m.
		40	5	2½	W.	3	b.c.	
		50	4	2				
		2 0	4	2				
		24	4½	1½				
		40	5	1				
		3 0	5	1				
		25	6	2 0	W.	2	b.c.	

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
⊙ Ap. 19.	......	3 30 P.M.	3 6½	1 11½				
		49	7	11				
		4 00	8	10				
		18	9	9½				
		4 43	3 10	1 9	....	1	b.c.	
		5 0	10½	8	E.N.E.	2	b.c.	
		20	11	8				
		35	11½	7				
		52	11½	7				
		6 25	......	6	E.	......	b.c.	
		40	......	5½				
		55	......	5½	E.	1	b.	
		7 10	......	5½				
		35	......	5½				
		50	......	5½				
		8 0	......	5½				
		30	......	5				
		55	......	4	....	......	....	Low Water 8^h 54^m.
		9 25	......	6				
		10 00	......	6				
		20	......	6½				
		40	......	7				
		50	......	9				
		11 15	......	10½				
		35	......	11	E.	2	b.	
		Midnight.	......	2 0				
		0 30 A.M.	......	2 2				
☽ 20.	......	1 0	......	2½				
		20	......	3				
		30	......	3½				
		2 0	......	2½	....	......	....	High Water 1^h 35^m.
		30	......	1				
		50	......	0				
		3 50	......	1 9½				
		4 0	......	9	E.	2	b.c.	
		30	......	8				
		40	......	7				
		5 00	......	6				
		30	......	5½				
		6 0	......	5½	....	......	....	Strong land breeze.
		10	4 0	5½				
		20	0½	5½	Calm.			
		30	0½	5½				
		40	1	5½	....	3	b.c	
		50	1	5¼	....	1		
		7 0	1	5¼	....	......	....	Low Water 6^h 55^m.
		10	1	5½				
		20	1	5½				
		30	1½	5½	Calm.			
		40	1½	6				
		50	0½	6	Calm.			
		8 15	0½	6	....	......	....	Tide irregular.
		44	4 0½	1 5½				
		40	0	5½	Calm.			
		9 0	0	6	Calm.			

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
☽ Ap. 20.	......	9 20 A.M.	4 0	1 7				
		31	0	7				
		45	0	7				
		10 0	3 11	7				
		15	11	7½				
		30	11	7½	W. ½ N.	2	b.c.	
		11 0	10	9	W.S.W.	3	b.c.	
		15	9	9½	....	3	b.c.	
		30	9	9½	....	3		
		45	8	10½	....	4	b.c.	
		12 0	8	10½	....	4	b.c.	
		30 P.M.	6	2 1				
		45	6	1	....	......	....	High Water. (The high water not well determined; batten and gauge differ.)
		1 0	6	1	....	3	b.c.	
		30	6	0½	W.S.W.	2	b.c.	
		2 0	6	0½	W.	3	b.c.	
		20	5½	1½				
		40	5	1				
		50	6	0½				
		3 0	6	0	....	4	b.c.	
		10	6½	1 11½				
		20	6½	11½				
		30	6½	11				
		40	7	10½	Calm.			
		50	7	10½				
		4 0	7½	10				
		10	8	9½	Calm.			
		20	9	8				
		40	10	8				
		5 0	11	7½	W.	2	b.c.	
		10	11	7½				
		20	10½	7				
		30	10	7	W.	3	b.c.	
		40	00	6	....	0	b.c.	
		6 0	......	6				
		20	......	5½				
		35	......	5	....	0	b.c.	
		45	......	4½				
		55	......	4				
		7 2	......	3½	E.	1	b.c.	
		20	......	3½	....	......	....	Low Water 7h 17m.
		35	......	4				
		45	......	4				
		55	......	4				
		8 5	......	4½				
		15	......	4½				
		8 40	......	1 5½				
		9 20	......	5½				
		40	......	5½				
		10 20	......	6½				
		50	......	7½				
		11 20	......	8				
		50	......	9				
		Midnight.	......	9½				
♂ Ap. 21.	......	0 25 A.M.	......	1 10				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♂ Ap. 21.	......	1 0 A.M.	......	2 0				
		30	......	2	......	......	......	High Water 1^h 57^m.
		2 0	......	3				
		30	......	2				
		3 0	......	1				
		40	......	1 10				
		4 5	......	9½				
		40	......	9				
		5 0	......	9				
		20	......	9				
		6 0	3 9	8½	Calm.	......	b.c.	
		20	10	8				
		7 0	11½	7				
		30	4 0	7				
		8 0	0	7	E.	2	b.c.	
		25	3 11½	8				
		40	11½	7				
		9 0	4 0	7				
		30	0	7				
		10 0	0	8				
		11 0	0	7	S.E.	3	b.c.	
		30	3 11	8	Calm.			
		Noon.	9	9	......	......	......	High Water, irregular.
		0 30 P.M.	8½	7½				
		1 0	8	7	N.W.	2	b.c.	
		30	7½	6½				
		2 0	7½	6½	Calm.			
		30	6½	5½				
		3 0	6½	5½	W.S.W.	2	b.c.	
		30	6	5				
		4 0	7	6	W.	2	b.c.	
		30	8	7				
		5 0	9	8	W.	2	b.c.	
		30	10	9				
		6 0	11	10				
		30	......	9	......	......	......	Tide irregular, ebbing and flowing at three hours intervals.
		7 0	......	6				
		30	......	5½	Calm.			
		8 0	......	1 6				
		30	......	6½				
		9 0	......	7½	S.E.	1		
		30	......	7				
		10 0	......	7½	......	2		
		30	......	7½				
		11 0	......	8	......	3		
		30	......	8				
		Midnight.	......	8	......	3	b.c.	
		0 30 A.M.	......	1 8¼				
☿ 22.	......	1 0	......	9	S.E.	1–3	b.c.	
		30	......	9½				
		2 0	......	10				
		30	......	10	......	......	......	High Water 2^h 30^m.
		3 0	......	10				
		30	......	9½				
		4 0	......	9½				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
☿ Ap. 22.	......	4 30 A.M.	......	9½				
		5 0	......	10				
		30	......	9				
		6 0	3 11½	9	S.E.	2	b.c.	
		30	11	7½	Calm.			
		7 0	4 0	7	....	......	b.	
		30	0	6				
		8 0	0	6	....	......	....	Low Water 8^h 3^m.
		30	0	6	....	......	r.	
		9 0	0	6½	....	......	b.c.	
		30	3 11½	7	N.W.	2		
		10 0	11	7	W.	2		
		30	11	7½	....	2		
		11 0	10½	8	....	2	b.c.	
		30	10	8	....	3		
		Noon.	10	8½	....	4	b.c.	
		0 30 P.M.	10	9	....	4	b.c.	
		1 0	9½	9				
		30	10½	8½				
		2 0	10	8½	....	4	b.c.	
		30	9	9				
		3 0	8½	10	....	4	b.c.	
		30	8	10				
		4 0	8	10	....	3	b.c.v.	
		30	8	10				
		5 0	8	10	....	......	....	High Water 4^h 20^m.
		30	8	10				
		6 0	7½	9½				
		30	......	9½	W.			
		7 0	......	8				
		30	......	7				
		8 0	......	1 6½	....	3		
		30	......	5½				
		9 0	......	5	....	......	....	Low Water 9^h 15^m.
		30	......	5½				
		10 0	......	6	....	3		
		30	......	6¼				
		11 0	......	7½				
		30	......	6½				
		Midnight.	......	8	....	3		
		0 30 A.M.	......	1 9				
♃ 23.	......	1 0	......	9½				
		30	......	9½				
		2 0	......	9½				
		30	......	9½	....	......	....	High Water 2^h 30^m.
		3 0	......	9½				
		30	......	9½				
		4 0	......	9½				
		30	......	9	E.	2	b.c.	
		5 0	......	8				
		30	......	8	....	0	b.c.	
		6 0	3 10½	8				
		30	10½	8				
		7 0	10½	7½	....	......	....	Low Water 7^h 0^m.
		30	10	8				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♃ Ap. 23.	......	8 0 A.M.	3 10	1 8				Tide ebbing and flowing at irregular intervals.
		30	10	8½	N.W.	1	b.c.	
		9 0	10	8½				
		30	9½	8½				
		10 0	9½	9	W.	2	b.c.	
		30	10	8				
		11 0	10	8				
		30	10	8	N.W.	2	b.c.	
		Noon.	10	8				
		0 30 P.M.	10½	8				
		1 0	10	8½				
		30	9½	8½	N.W.	4	b.c.	
		2 0	9½	8½				
		30	9	9	N.W.	2	b.c.	
		3 0	9	10	....	2	b.c.	
		30	9	9½	N.	3	b.c.	
		4 0	9	10	....	2	b.c.	
		30	9	10½	....	2	b.c.	
		5 0	9	9¾	Calm.			
		30	9	9½	S.E.	1	b.c.	
		6 0	9	9	....	2	b.c.	
		30	......	9				
		7 0	......	9	....	0	b.c.	
		30	......	9				
		8 0	......	1 9				
		30	......	8½				
		9 0	......	8½	S.E.	1	b.c.	
		30	......	8½				
		10 0	......	9				
		30	......	9	....	5	b.c.	
		11 0	......	9½	....	5	b.c.	
		30	......	9				
		Midnight.	......	8				
		0 30 A.M.	......	1 7	S.E.	2	b.c.	
♀ 24.	......	1 0	......	7				
		30	......	6½				
		2 0	......	6½				
		30	......	6				
		4 0	......	6	S.	2	b.c.	Low Water 4^h 0^m.
		30	......	6				
		5 0	......	6				
		30	......	6½	S.S.E.	2–4	b.c.	
		6 0	3 11	7				
		30	11	7½	S.E.	1	b.c.	
		7 0	10½	8	....	1		
		30	10	9	....	1		
		8 0	9½	9	E.	1	b.c.	
		30	9½	8½	Calm.	......	b.c.	
		9 0	10	8½				
		30	9	9	N.E.	1	b.c.	
		10 0	9	9	Calm.			
		30	9	10	W.N.W.	1	b.c.	High Water 10^h 30^m.
		11 0	10	9½	W.S.W.	3	b.c.	
		30	10	9	....	3	b.c.	
		Noon.	10	8¾				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♀ Ap. 24.	......	0 30 P.M.	3 10½	1 8	....	2	b.c.	Tide ebbing and flowing at intervals of two hours.
		1 0	10½	7½	....	......	b.c.	
		30	10½	8	Calm.			
		2 0	10½	7½				
		30	10½	7	Variable.	......	b.	Low Water 2^h 30^m.
		3 0	11	7½	Calm.			
		30	11	7½				
		4 0	10½	8	E.	1	b.c.	
		30	10	7½				
		5 0	9½	7¾	Calm.	......	b.c.	
		30	9	9				
		6 0	......	8½	S.E.	1	b.c.	
		30	......	8½				
		7 0	......	9				
		30	......	9	S.E.			
		8 0	......	1 9	S.	3	b.c.	
		30	......	8½				
		9 0	......	9	S.E.	2	b.c.	
		30	......	9				
		10 0	......	9	E.S.E.	3	b.	
		30	......	9				
		11 0	......	9	E.	1	b.c.	
		30	......	9¼				
		Midnight.	......	9½	Variable.	1	b.	High Water 0^h 0^m.
		0 30 A.M.	......	1 9				
♄ 25.	......	1 0	......	9				
		30	......	8				
		2 0	......	7½	S.E.	1	b.c.	
		30	......	7				
		3 0	......	6½				
		30	......	6	S.E.	3	b.c.	
		4 0	......	6				
		30	......	6	....	......	....	Low Water 4^h 15^m.
		5 0	......	6½	S.E.	3	b.c.	
		30	......	6½				
		6 0	......	7	S.E.	2	b.c.	
		30	3 11	7½				
		7 0	11	8	S.S.E.	1	b.c.	
		30	11	8	....	1	b.c.	
		8 0	11	8	E.N.E.	2	b.c.	
		30	10	9				
		9 0	9½	10	E.	1	b.c.	
		30	9	10	Calm.			
		10 0	9	10½	W.N.W.	1–3	b.c.	
		30	8½	10½	....	......	....	High Water 10^h 15^m.
		11 0	8	10	N.W	3	b.c.	
		30	8½	9½				
		Noon.	8½	9	N.E.	1	b.c.	
		0 30 P.M.	9	9				
		1 0	9½	8	N.N.E.	4–2	b.c.	
		30	10	8	Calm.			
		2 0	10	7	N.W.	3	b.c.	
		30	4 0	6½				
		3 0	0½	6	N.W.	4	b.c.	
		30	1	6	....	......	....	Low Water 3^h 30^m.

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
♄ Ap. 25.	......	4 0 P.M.	4 $0\frac{1}{2}$	1 6	N.W.	4	b.c.	
		30	0	$6\frac{1}{2}$				
		5 0	0	7	S.	2		
		30	3 $11\frac{1}{2}$	7	....	3		
		6 0	$11\frac{1}{2}$	8				
		30	......	$9\frac{1}{2}$	S.	2	b.c.	
		7 0	......	10				
		30	......	1 $10\frac{1}{2}$				
		8 0	......	11	....	3	b.c.	
		30	......	11				
		9 0	......	11				
		30	......	11	....	3	b.c.	High Water 9^h 15^m.
		10 0	3 $7\frac{1}{2}$	11				
		30	......	11	....	5	b.c.	
		11 0	......	$10\frac{1}{2}$				
		30	......	10	....	3		
		Midnight.	......	9	S.S.E.	2	b.c.	
		0 30 A.M.	......	1 8				
⊙ 26.	......	1 0	......	7	S.S.E.	3	b.c.	
		30	......	6				
		2 0	......	5	....	3	b.c.	
		30	......	5				
		3 0	......	$4\frac{3}{4}$				
		30	......	$4\frac{1}{2}$				
		4 0	......	$4\frac{1}{2}$	S.S.E.	3–4	b.c.	Low Water 4^h 0^m.
		30	......	$4\frac{1}{2}$				
		5 0	......	$4\frac{1}{2}$				
		30	......	5				
		6 0	......	5	S.	2	b.c.	
		30	4 0	6				
		7 0	3 $11\frac{1}{2}$	7	S.E.	1	b.c.	
		30	$10\frac{1}{2}$	$8\frac{1}{2}$				
		8 0	$9\frac{1}{2}$	9	Calm.			
		30	9	9				
		9 0	$8\frac{1}{2}$	$9\frac{1}{2}$	Variable.			
		30	$8\frac{1}{2}$	10				
		10 0	8	10	N.N.E.	3	b.c.	
		30	$7\frac{1}{2}$	10	....	......	....	High Water 10^h 30^m.
		11 0	$7\frac{1}{2}$	10	N.N.E.	4	b.c.	
		30	$7\frac{3}{4}$	10				
		Noon.	$8\frac{3}{4}$	10				
		0 30 P.M.	10	$9\frac{1}{2}$				
		1 0	11	8				
		30	$11\frac{1}{2}$	$6\frac{1}{2}$	N.	4	b.	
		2 0	$11\frac{1}{2}$	$6\frac{1}{4}$				
		30	$11\frac{3}{4}$	6	....	5	b.	
		3 0	4 $0\frac{1}{4}$	5				
		30	$1\frac{1}{2}$	4	....	5	b.	
		4 0	......	1 4	N.	2	b.c.	Low Water 4^h 15^m.
		30	......	4				
		5 0	......	4	Variable.			
		30	......	4	S.	1	b.	
		6 0	......	4				
		30	......	$4\frac{1}{2}$				
		7 0	......	$5\frac{1}{2}$				

Table. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m	ft. in.	ft. in.				
☽ Ap. 26.	......	7 30 P.M.	......	1 8	Calm.	0	b.c.	
		8 0	......	1 9	Variable.			
		30	......	10	S.S.E.	3	b.c.	
		9 0	......	1 11	....	5	b.	
		30	......	1 11½				
		10 0	3 6	2 0	....	3–5	b.	High Water 10h 0m.
		30	......	1 11½				
		11 0	......	1 11				
		30	......	1 10½				
		Midnight.	......	1 10	S.E.	4	b.	
☽ 27.	......	0 30 A.M.	......	1 9				
		1 0	......	1 8				
		30	......	1 7	E.	2	b.	
		2 0	......	1 7				
		30	......	1 6				
		3 0	......	1 5	E.N.E.	3	b.c.	
		30	......	1 4	....	3		
		4 0	......	1 3½				
		30	......	1 3½				
		5 0	......	1 3				
		30	......	1 3				
		6 0	4 2	1 3½				
		30	4 1	1 4½	S.E.	3	b.	Low Water 5h 10m.
		7 0	4 1	1 4½				
		30	3 11½	1 6				
		8 0	3 10	1 7½	Variable.	2	b.c.	
		30	3 9	1 8½	Calm.	0	b.	
		9 0	3 8½	1 9				
		30	3 8	1 9½				
		10 0	3 7½	1 10	N.	1	b.c.	
		30	3 7	1 10½				
		11 0	3 7	1 11	....	2	....	High Water 11h 0m.
		30	3 8	1 10				
		Noon.	3 9½	1 9	N.N.W.	3	b.c.v.	
		0 30	3 10	1 8				
		1 0	3 10½	1 7	N.W. by N.	4	b.c.	
		30	3 11	1 6				
		2 0	4 0	1 5				
		30	4 1	1 4	Calm.	0	b.c.	
		3 0	4 2	1 3½	W.S.W.	1		
		30	4 2½	1 2½				
		4 0	4 3¼	1 2	....	......	....	Low Water 4h 0m.
		30	4 3½	1 2¼	Calm.	0	b.c.	
		5 0	4 3½	1 3				
		30	4 3	1 3	S.W.	2		
		6 0	4 2	1 4				
		0	4 2	1 4	S.W.	2	b.c.	
		30	......	1 4				
		7 0	......	1 4				
		30	......	1 5				
		8 0	......	1 6½				
		30	......	1 8	S.E.	2–4	b.	
		9 0	......	1 11				
		30	......	2 0½				
		10 0	......	2 2	....	......	....	High Water 10h 30m.

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
☽ Ap. 27.	......	10 30 P.M.	......	2 2	Variable.	1	b.	
		11 0	......	2 2				
		30	......	2 1½	S.	3	b.	
		Midnight.	......	2 1				
	......	0 30 A.M.	......	2 1				
♂ 28.		1 0	......	2 0				
		30	......	1 10				
		2 0	......	1 8				
		30	......	1 6				
		3 0	......	1 5	S.	3	b.c.	
		30	......	1 4				
		4 0	......	1 3				
		30	......	1 3	S.E.	4		
		5 0	......	1 2½	....	4	....	Low Water 5^h 15^m.
		30	4 2	1 2½	....	3		
		6 0	4 1½	1 3				
		30	4 1½	1 3½				
		7 0	4 0	1 5	E.	2	b.c.	
		30	3 11½	1 5½				
		8 0	3 10	1 7½				
		30	3 9½	1 8½				
		9 0	3 8½	1 9½	W.	3	b.c.	
		30	3 8	1 10				
		10 0	3 7	1 11	N.	1	b.c.	
		30	3 6	2 0	....	......	....	High Water 11^h 00^m.
		11 0	3 6½	2 0½	N.N.E.	3		
		30	3 7	2 0				
		Noon.	3 8	1 11	N.N.W.	5	b.c.	
		0 30 P.M.	3 9½	1 8				
		1 0	3 10	1 7	N.N.E.	2–4	b.c.	
		30	3 10	1 7				
		2 0	4 0	1 6				
		30	4 0½	1 5½	N.W.	4	b.c.	
		3 0	4 1	1 5	....	......	....	Low Water 3^h 30^m.
		30	4 0½	1 5				
		4 0	4 0	1 5	N.W.	4	b.c.	
		30	4 0	1 5½				
		5 0	3 11½	1 6	S.	2–3	b.c.	
		30	3 11½	1 6				
		6 0	3 11	1 7	S.	2	b.c.	
		0	3 11	1 7				
		30	......	1 7				
		7 0	......	1 8				
		30	......	1 8½				
		8 0	......	1 9	S.	2	b.c.	
		30	......	1 9½				
		9 0	......	1 11				
		30	......	1 11	....	3	b.c.	
		10 0	3 7½	1 11				
		30	......	1 11				
		11 0	......	1 10½	....	5	b.c.	
		30	......	1 10				
		Midnight.	......	1 9	....	3	b.c.	
☿ 29.	......	0 30 A.M.	......	1 9	S.S.E.	2	b.c.	

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
☿ Ap. 29.	......	1 0 A.M.	......	1 8				
		30	......	1 7				
		2 0	......	1 6	S.S.E.	3	b.	
		30	......	1 6				
		3 0	......	1 5¾				
		30	......	1 5½				
		4 0	......	1 5½	S.S.E.	3–4	b.	
		30	......	1 5				
		5 0	......	1 5				
		30	......	1 5				
		6 0	4 1	1 5	S.	2	b.c.	
		30	4 0	1 6	S.E.	1	b.c.	
		7 0	3 11½	1 7				
		30	3 10½	1 8				
		8 0	3 9½	1 9	Calm.			
		30	3 9	1 10				
		9 0	3 8½	1 10½	N. by E.	2	b.c.	
		30	3 8	1 11				
		10 0	3 8	1 11				
		30	3 7½	1 11				
		11 0	3 7½	1 11¼	N.N.E.	4	b.c.	
		30	3 8	1 11				
		Noon.	3 8¾	1 10½				
♀ May 1.	......	8 20 A.M.	......	1 8	Calm.	0	b.	
		8 37	......	1 9				
		8 55	......	1 10				
		9 25	......	1 11	N.W.	2	b.c.	
		10 00	......	2 0				
		35	......	2 1	....	3		
		11 20	......	2 2	W.N.W.	4		
		40	......	2 2	....	5		
		0 25 P.M.	......	2 1				
		1 10	......	2 0	W.	......	....	High Water 11^h 30^m.
		30	......	1 11				
		50	......	1 10	W.	5	b.c.	
		2 15	......	1 9				
		45	......	1 8				
		3 30	......	1 7				
		50	......	1 6	W.N.W.	3		
		4 10	......	1 5	N.W.	2		
		15	......	......	N.	2		
		55	......	1 4	N.N.E.	2	b.	
		5 20	......	1 3½	E.N.E.	......	b.c.	
		50	......	1 3	E.S.E.	1	c.	
		6 25	......	1 2½	S.E.	2		
		45	......	1 2½	....	......	....	Low Water 6^h 20^m.
		7 0	......	1 3				
		27	......	1 4	S.E. by S.	3–5	b.c.	
		50	......	1 5				
		8 15	......	1 6	....	......	b.	
		40	......	1 7				
		9 0	......	1 8				
		25	......	1 9				
		45	......	1 10				
		10 15	......	1 11	....	2	b.	

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♀ May 1.	......	10 35 P.M.	......	2 0				
		11 0	......	2 1				
		30	......	2 2				
		50	......	2 3	....	1–2	b.	
		0 15 A.M.	......	2 $3\frac{1}{2}$				
♄ May 2.	......	1 0	......	2 $3\frac{1}{2}$	S.E.	1	b.	
		20	......	2 $3\frac{1}{2}$	....	......	....	High Water 0^h 49^m.
		35	......	2 3				
		50	......	2 2				
		2 05	......	2 1				
		20	......	2 0				
		45	......	1 11				
		3 15	......	1 10				
		35	......	1 9	S.E.	2	b.	
		50	......	1 8				
		4 20	2 $3\frac{1}{2}$	1 7				
		40	2 $3\frac{1}{2}$	1 6				
		5 5	3	1 5	S.E.	2–3	b.	
		30	2 2	1 4				
		6 5	2 1	1 3				
		40	2 0	1 3	....	......	....	Low Water 6^h 30^m.
		7 40	1 11	1 4				
		8 0	1 10	1 5	....	2		
		20	1 9	1 6	....	1		
		40	1 8	1 7	Calm.			
		9 5	1 7	1 8				
		25	1 6	1 9	W.	1	b.	
		45	1 5	1 10				
		10 3	1 4	1 11	....	2		
		32	1 3	2 0	....	4		
		55	......	2 1	....	3	b.	
		11 10	......	2 2				
		30	......	2 3				
		Noon.	......	2 4	N.	4	b.	
		12 25 P.M.	......	2 3	....	......	....	High Water 11^h 55^m.
		40	......	2 2				
		1 0	......	2 1				
		2 0	......	2 0	N.N.E.	5	b.c.	
		20	......	1 11				
		40	......	1 10				
		3 30	......	1 9				
		4 0	......	1 8	N.E.	5		
		20	......	1 7				
		40	......	1 5	S.W.	4	o.c.g.	
		5 20	......	1 4	E.	3	b.c.	
		6 25	......	1 $3\frac{1}{2}$				
		7 0	......	1 3	N.E.	1	....	Low Water 6^h 52^m.
		30	......	1 3				
		8 0	......	1 4	S.E.	1		
		30	......	1 5				
		9 0	......	1 6	....	5	b.	
		20	......	1 7				
		32	......	1 8				
		45	......	1 9				
		10 39	......	1 11				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m	ft. in.	ft. in.				
♄ May 2.	......	11 6 P.M.	......	2 0	E.	1	b.c.	
		34	......	2 1	E.N.E.	1	b.c.	
		0 2 A.M.	......	2 2				
⊙ 3.	......	30	......	2 3				
		1 10	......	2 3	....	......	....	High Water 0^h 51^m.
		40	......	2 2				
		2 10	......	2 1				
		35	......	2 0				
		35	......	2 0				
		3 5	......	1 11				
		30	......	1 10	S.E.	2	b.	
		4 0	......	1 9				
		25	......	1 8				
		5 0	......	1 7				
		20	......	1 6	....	1	b.	
		50	......	1 5				
		6 30	......	1 4	....	.....	....	Low Water 6^h 49^m.
		7 10	......	1 4				
		50	......	1 5	Calm.	0	b.	
		8 15	......	1 6				
		35	......	1 7	....	0		
		9 10	......	1 8				
		40	......	1 9	W.	1	b.c.	
		10 5	......	1 10	W.S.W.	4		
		25	......	1 11				
		45	......	2 0				
		11 7	......	2 1				
		30	......	2 2				
		Noon.	......	2 $2\frac{1}{2}$	....	.....	....	High Water 0^h 24^m.
		1 0 P.M.	......	2 2				
		2 0	......	2 1	S.	5	o.c.g.	
		25	......	2 0				
		55	......	1 11				
		3 20	......	1 10	....	2		
		50	......	1 9	....	5	o.c.	
		4 5	......	1 8				
		25	......	1 7				
		5 9	......	1 6				
		40	......	1 5				
		6 0	......	1 4	....	......	....	Low Water 6^h 57^m.
		40	......	1 3	S.	3	c.	
		7 10	......	1 3				
		50	......	1 4	....	2	c.	
		8 30	......	1 5				
		9 10	......	1 6	....	2	b.	
		35	......	1 7				
		10 5	......	1 8	....	1	b.	
		25	......	1 9	....	3		
		50	......	1 10				
		11 15	......	1 11	....	0		
		35	......	2 0				
		Midnight.	......	2 1	....	2	b.	
☽ 4.	......	0 25 A.M.	......	2 2				
		55	......	2 3				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind. Direction.	Wind. Force.	Weather.	Remarks.
	h m	h m		ft. in.				
☽ May 4.	......	1 30 A.M.	......	2 3	Calm.	0	b.c.	
		55	......	2 2	....	......	....	High Water 1^h 11^m.
		2 20	......	2 1				
		35	......	2 0				
		50	......	1 11	S.S.E.	1	b.	
		3 25	......	1 10	....	2–3	b.	
		50	......	1 9				
		4 15	......	1 8				
		40	......	1 7				
		5 10	......	1 6	S.	5	b.	
		6 0	......	1 6	....	3	b.	
		35	......	1 5				
		7 15	......	1 5	Calm.	......	b.	
		8 0	......	1 4½	Calm.			
		45	......	1 5				
		9 10	......	1 6	W.	1	b.	
		50	......	1 7	....	......	....	Low Water 7^h 37^m.
		10 10	......	1 8	W.S.W.	4	b.c.	
		25	......	1 9	....	5		
		38	......	1 10				
		49	......	1 11				
		11 00	......	2 00				
		50	......	2 1				
		0 25 P.M.	......	2 2				
		1 20	......	2 2	....	......	....	High Water 1^h 16^m.
		2 40	......	2 2	N.	6	b.c.	
		3 25	......	2 0				
		4 0	......	1 11				
		15	......	1 10				
		30	......	1 9				
		45	......	1 8				
		5 5	......	1 7	Calm.			
		40	......	1 6	S.S.W.	1	b.c.	
		6 10	......	1 5	....	......	....	Low Water 7^h 15^m.
		40	......	1 5	S.E.	1	b.	
		7 20	......	1 5				
		8 0	......	1 5				
		9 40	......	1 6				
		10 10	......	1 7	....	3	b.	
		30	......	1 8				
		40	......	1 9				
		50	......	1 10				
		11 5	......	1 11				
		20	......	2 0				
		55	......	2 1				
♂ 5.	......	0 40 A.M.	......	2 2				
		1 45	......	2 1	S.S.E.	1	b.	
		2 30	......	2 0	S.E.	3		
		3 20	......	1 11	....	......	....	High Water 0^h 45^m.
		55	......	1 10				
		4 25	......	1 9	Calm.	0	b.	
		50	......	1 8				
		5 30	......	1 7				
		6 20	......	1 6	S.E.	1	b.	
		50	......	1 6				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m		ft. in.				
♂ May 5.	......	7 25 P.M.	......	1 6				
		55	......	1 7	Calm.	0	b.	Low Water 6^h 32^m.
		8 15	......	1 7				
		40	......	1 7	W.	1	b.	
		9 50	......	1 8				
		10 40	......	1 9				
		11 20	......	1 10	E.	4	b.c.	
		40	......	1 11	Variable.			
		Noon	......	2 0	W.	4	b.c.	
		0 5 P.M.	......	2 2	W.S.W.	4–5	b.c.	
		40	......	2 2	....	......	....	High Water 0^h 57^m.
		1 5	......	2 2				
		30	......	2 2				
		2 35	......	2 1				
		3 10	......	2 0	Variable.	3	b.c.	
		30	......	1 11				
		4 10	......	1 10				
		5 10	......	1 9	N.	3	b.c.	
		6 5	......	1 8	E.N.E.	5	b.	
		40	......	1 7				
		7 0	......	1 7				
		25	......	1 6½	E.	3	b.	
		8 00	......	1 6				
		30	......	1 6	Calm.	0	b.	Low Water 8^h 30^m.
		9 0	......	1 6				
		35	......	1 6				
		10 10	......	1 7				
		50	......	1 8				
		11 30	......	1 9				
☿ 6.	......	0 10 A.M.	......	1 10	E.	2	b.	
		50	......	1 11				
		1 35	......	1 11	....	......	....	High Water 2^h 27^m.
		2 5	......	2 0	Calm.	0	b.	
		40	......	2 0	E.	3	b.	
		3 30	......	1 11				
		4 10	......	1 10				
		50	......	1 9	S.E.	3	b.	
		5 30	......	1 8				
		6 10	......	1 7				
		55	......	1 6				
		7 25	......	1 7	....	......	....	Low Water 7^h 57^m.
		8 20	......	1 7				
		9 10	......	1 7	W.	3	b.c.	
		50	......	1 7				
		10 30	......	1 8	....	5		
		11 0	......	1 9				
		30	......	1 10				
		0 40 P.M.	......	1 11	W.	5	b.c.	
		1 40	......	2 0½				
		2 40	......	2 0½	N.	4	b.c.	
		50	......	2 0	....	......	....	High Water 2^h 43^m.
		3 20	......	2 0				
		40	......	2 0				
		4 40	......	1 11	Calm.	0	b.c.	
		5 10	......	1 10				

TABLE. (Continued.)

Date.	Moon's Age.	Mean Time.	Tide-gauge.	Tide-batten.	Wind.		Weather.	Remarks.
					Direction.	Force.		
	h m	h m		ft. in.				
☿ May 6.	......	5 50 P.M.	......	1 9				
		6 30	......	1 8	E.	1	b.c.	
		7 30	......	1 7				
		8 0	......	1 6½				
		9 0	......	1 7	....	......	....	Low Water 8^h 22^m.
		10	......	1 7				
		10 0	......	1 8				
		11 0	......	1 9				
♃ 7.	......	3 40 A.M.	......	1 6				
		5 40	......	1 7	E.	1	b.	
		6 10	......	1 8				
		50	......	1 9	....	......	....	High Water 9^h 25^m.
		7 15	......	1 8				
		40	......	1 7	S.E.	0	b.	
		8 20	......	1 7				
		9 0	......	1 7	....	......	....	Tide irregular.
		50	......	1 7	N.W.	2	b.c.	
		10 30	......	1 7	W.	3		
		11 20	......	1 7				
		0 20 P.M.	......	1 8				
		0 50	......	1 9	N.W.	4		
		2 55	......	1 10				
		3 55	......	1 10	N.E.	3	b.c.	
		5 40	......	1 11				
		6 25	......	1 11	....	......	....	High Water 6^h 25^m.
		7 10	......	1 10	....	......	....	Low Water 11^h 17^m.
8.		3 15	......	1 10	....	......	....	High Water 3^h 18^m.

METEOROLOGICAL JOURNAL,

KEPT BY THE ASSISTANT SECRETARY,

AT THE APARTMENTS OF THE

ROYAL SOCIETY,

BY ORDER OF

THE PRESIDENT AND COUNCIL.

OBSERVANDA.

Height of the Cistern of the Barometer above the plinth at Waterloo Bridge....83 feet 2 inches.
——————— above the mean level of the sea ....97 feet.
Height of the receiver of the Rain Gauge above the court of Somerset House ..79 feet.
The External Thermometer is 2 feet higher than the Barometer Cistern.
The Thermometers are graduated to Fahrenheit's scale.
The Barometer is divided into inches and tenths.
The Hours of Observation are of Mean Time, the day beginning at Midnight.
The *daily* observations of the Barometer are *not* corrected.
The *monthly means* are corrected for capillarity and temperature by the Table contained in Mr. Baily's paper in *Phil. Trans.* for 1837.

METEOROLOGICAL JOURNAL FOR JULY AND AUGUST, 1842.

1842.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M., deg. Fahr.	Diff. of Wet and Dry Bulb Thermometer.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering. Lowest	External Thermometers. Self-registering. Highest	Rain in Inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
JULY															
F 1	29.814	29.806	64.0	29.904	29.896	66.4	57	02.6	51.3	65.2	52.3	70.0	.111	W	A.M. Overcast—light rain and wind. P.M. Cloudy—light wind. Evening, Overcast—light rain.
S 2	29.914	29.908	81.2	29.894	29.886	68.3	55	08.3	63.0	65.7	52.2	76.6	.316	W	Cloudy—light breeze, with occasional showers throughout the day. Evening, Starlight—light clouds.
☉ 3	30.034	30.026	79.0	30.010	30.002	69.0	57	08.3	62.8	69.3	52.0	77.6	.213	W	Cloudy—lt. breeze throughout the day. Ev. Overcast—slight rain.
M 4	29.806	29.800	65.3	29.758	29.750	69.0	60	06.6	64.7	71.7	58.8	71.4	.100	S	A.M. Overcast—light breeze. P.M. Cloudy. Evening, Fine and starlight—light clouds. Rain in the night.
T 5	29.746	29.740	82.8	29.796	29.792	69.4	59	10.0	66.7	68.5	61.4	75.7	.055	SSE var.	Cloudy—very high wind, with occasional showers throughout the day. Rainbow at ½ p. 6. Evening, Overcast—rain.
W 6	30.136	30.130	83.4	30.184	30.178	69.0	52	09.3	62.3	67.2	52.4	79.4	.033	W	A.M. Fine—lt. clouds & breeze. P.M. Cloudy—lt. breeze. Ev. Fine and starlight.
T 7	30.150	30.142	67.2	30.032	30.024	65.8	55	08.2	63.2	59.0	52.3	72.7	.022	SSE	A.M. Cloudy—stiff breeze—rain in the night. P.M. Overcast—light rain & breeze. Ev. The same.
○ F 8	29.856	29.848	70.4	29.776	29.768	66.4	56	06.7	61.8	64.3	54.0	66.6	.041	S	A.M. Fine—light clouds and breeze. P.M. Cloudy—high wind. Evening, Cloudy—light showers.
S 9	29.748	29.742	73.3	29.790	29.782	66.0	58	07.7	62.8	62.4	54.3	73.3	.102	W	A.M. Cloudy—light breeze. P.M. Overcast—light rain and wind. Evening, Cloudy—light rain.
☉ 10	29.970	29.962	80.8	29.950	29.946	68.0	57	08.0	62.2	69.0	53.2	77.8	.116	S	Fine—light clouds and breeze throughout the day. Ev. Cloudy.
M 11	29.724	29.718	68.0	29.650	29.644	68.9	61	07.0	67.2	73.4	56.3	82.7	.072	S	Cloudy—high wind throughout the day. (Rain—high wind during the night.) Evening, Cloudy—light rain.
T 12	29.922	29.914	76.0	30.020	30.012	70.0	59	08.0	65.0	71.5	58.0	75.2	.038	WNW	A.M. Cloudy—lt. breeze. P.M. Fine—lt. clds. Ev. Fine & starlight.
W 13	30.212	30.204	69.7	30.242	30.234	70.4	60	07.8	66.5	70.8	57.3	76.2		SW var.	A.M. Cloudy—stiff breeze. P.M. Dark heavy clouds—stiff breeze. Evening, Fine and starlight.
T 14	30.432	30.424	83.6	30.402	30.394	70.6	60	07.0	63.2	70.3	55.0	76.3		W	Fine—light clouds and breeze throughout the day. Evening, Fine and starlight.
F 15	30.468	30.462	81.0	30.356	30.348	69.8	54	09.8	64.3	71.7	56.0	76.3		N	A.M. Fine—light clouds and breeze. P.M. Fine & cloudless. Evening, Fine and starlight.
S 16	30.250	30.246	84.0	30.150	30.142	69.4	59	07.5	62.8	65.8	54.6	73.2		E	Fine—lt. clouds & breeze throughout the day. Ev. Fine & moonlight.
☉ 17	29.978	29.972	84.5	29.890	29.886	70.0	63	07.2	64.0	65.8	57.3	74.6		E	Fine—light clouds—stiff breeze throughout the day. Ev. Overcast.
M 18	29.886	29.882	70.2	29.894	29.888	70.4	62	06.7	67.2	75.8	59.7	75.6	.036	NW	A.M. Cloudy—lt. fog and breeze. Rain in the night. P.M. Cloudy. Evening, The same.
T 19	29.888	29.880	68.4	29.842	29.836	70.4	61	05.9	64.3	68.8	62.0	77.8		E	Cloudy—light breeze throughout the day—shower early. Evening, Dark heavy clouds—light rain.
W 20	29.790	29.784	76.2	29.768	29.762	69.0	60	07.3	64.7	63.0	57.3	71.0	.033	S	A.M. Fine—light clouds and breeze. P.M. Cloudy—light showers. Ev. Moonlight, with lightning.
T 21	29.772	29.766	67.3	29.834	29.826	66.5	61	05.9	60.8	60.4	56.8	72.4	.038	W	A.M. Ovct.—lt. rain & breeze. P.M. Cloudy, with occasionally slight rain. Ev. Fine & moonlight.
● F 22	30.046	30.040	78.8	30.108	30.100	66.7	54	08.0	59.8	61.7	52.6	72.2	.025	NW	Cloudy—light breeze throughout the day. Evening, The same.
S 23	30.262	30.256	67.3	30.246	30.238	65.6	52	06.7	58.4	64.5	55.0	64.4		NNW	A.M. Cloudy—light breeze. P.M. Fine—light clouds and breeze. Evening, Fine and moonlight—light fog.
☉ 24	30.180	30.174	76.2	30.076	30.070	67.2	58	07.2	64.3	73.5	53.7	79.7		NNW	A.M. Thick haze—light breeze. P.M. Cloudy—light breeze. Ev. Fine and moonlight.
M 25	29.966	29.958	65.0	29.954	29.946	69.0	63	05.2	64.7	68.2	57.6	76.7		E	A.M. Cloudy—light breeze. P.M. Fine—light clouds and breeze. Evening, Fine and moonlight.
T 26	30.046	30.040	79.8	30.062	30.054	68.8	58	06.7	61.7	69.3	52.4	72.3		N	Fine—lt. clouds & breeze throughout the day. Ev. Fine & starlight.
W 27	30.212	30.204	63.6	30.200	30.192	66.7	58	05.2	57.4	68.7	56.8	71.4	.050	E	A.M. Ovct.—lt. rain. P.M. Fine—lt. clds. & breeze. Ev. Ovct.—slt. rain. ½ p. 12, very hvy. thunder & vivid lightning, until ¼ to 6.
T 28	30.112	30.104	70.0	30.020	30.012	67.4	60	02.8	61.3	69.8	56.3	70.3	.091	W	A.M. Overcast—thunder and lightning until ½ p. 6. At ¾ to 6, very heavy rain. P.M. Fine—lt. clouds. Ev. Moonlight—lt. clouds.
F 29	29.910	29.902	64.8	29.942	29.936	66.3	53	01.7	53.0	61.2	55.2	71.6	.205	N	A.M. Overcast—light rain and wind. P.M. Fine—light clouds—stiff breeze. Evening, Fine and starlight.
S 30	30.082	30.074	63.2	30.096	30.090	64.3	52	07.2	57.3	62.7	50.4	64.4	.150	NW	Cloudy—lt. breeze throughout the day. Ev. Fine & starlight—lt. clds.
☉ 31	30.186	30.178	61.8	30.206	30.198	64.4	53	05.7	57.8	64.8	55.7	64.5		NW	A.M. Ovct.—lt. wind. P.M. Cloudy—lt. breeze. Ev. Fine & starlt.
MEAN.	30.016	30.009	73.1	30.002	29.995	68.1	58	06.8	62.1	67.2	55.5	73.5	Sum. 1.847		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.901 .. 29.900 C. 29.893 .. 29.893
AUGUST															
M 1	30.340	30.334	62.5	30.310	30.302	64.0	53	03.5	58.0	67.3	55.5	67.0		N	Overcast—light wind throughout the day. Evening, The same.
T 2	30.230	30.226	62.0	30.112	30.108	64.5	54	05.0	60.0	70.6	55.0	69.0	.186	SSE	A.M. Overcast—light wind. P.M. Fine—light clouds—brisk wind. Evening, The same.
W 3	30.004	30.000	65.0	29.950	29.944	68.0	62	02.5	64.2	77.4	58.5	71.5	.027	N	A.M. Overcast—light wind. P.M. Fine—light clouds and wind. Evening, The same.
T 4	29.916	29.912	73.0	29.884	29.878	70.5	60	06.5	70.0	80.0	61.0	78.5		N	A.M. Fine—light clouds and wind. P.M. Lightly overcast—brisk wind. Ev. Fine—lt. clouds & wind.
F 5	29.998	29.994	70.0	29.982	29.976	71.0	63	06.5	69.4	73.8	64.5	81.5		S	A.M. Overcast—brisk wind. P.M. Fine—light clouds—brisk wind. Ev. The same.
S 6	29.968	29.964	69.0	29.974	29.970	70.0	64	05.5	68.2	68.6	63.2	75.5		S	A.M. Overcast—light rain & wind. P.M. Slightly overcast—light wind. Evening, Overcast—light rain.
○☉ 7	30.040	30.036	71.2	30.000	29.996	70.4	56	07.0	65.0	73.0	60.0	70.5	.172	SE var.	Fine—light clouds and wind throughout the day. Ev. The same.
M 8	30.110	30.104	72.0	30.090	30.084	71.0	60	06.9	68.0	74.5	58.0	74.5		S	A.M. Lightly overcast—light wind. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
T 9	30.092	30.086	74.0	30.004	30.000	72.0	59	08.4	69.8	77.0	60.2	80.0		ESE	Fine—nearly cloudless—brisk wind throughout the day. Ev. Fine & starlight.
W 10	29.794	29.790	74.0	29.660	29.656	75.0	63	12.5	80.0	83.6	66.0	82.5		SE	A.M. Fine—light clouds and wind. P.M. Overcast—brisk wind. Ev. Overcast—heavy rain, with thunder and lightning.
T 11	29.936	29.932	76.0	30.090	30.084	72.0	57	08.2	65.0	69.9	62.0	87.0	.250	E var.	Fine—light clouds, with brisk wind throughout the day. Evening, Fine and starlight.
F 12	30.350	30.346	74.0	30.334	30.328	72.0	58	06.8	66.4	73.0	59.5	76.0	.138	SSE	A.M. Fine—light clouds—brisk wind. P.M. Fine and cloudless—brisk wind. Evening, Fine and starlight—brisk wind.
S 13	30.468	30.462	69.0	30.472	30.466	71.2	64	03.5	67.5	73.5	61.2	76.0	.172	S	Overcast—light wind throughout the day. Ev. Fine and starlight.
☉ 14	30.472	30.466	72.0	30.396	30.392	73.0	65	06.0	72.0	79.6	65.2	75.2	.083	W	A.M. Light fog. P.M. Fine—light clouds and wind. Evening, Fine and starlight—light wind.
M 15	30.288	30.282	73.0	30.210	30.204	74.0	65	05.0	70.7	83.0	61.0	80.2		ESE	A.M. Light fog. P.M. Fine—nearly cloudless. Ev. Fine & starlight.
T 16	30.248	30.244	73.5	30.216	30.210	74.0	63	10.0	72.7	81.7	63.4	84.0		ENE	Fine—lt. clouds and wind throughout the day. Ev. Fine & starlight.
W 17	30.186	30.182	73.4	30.104	30.098	74.0	62	05.5	67.0	74.2	61.5	82.5		E	Fine—nearly cloudless—brisk wind throughout the day. Evening, Fine and moonlight.
T 18	30.012	30.006	74.0	29.950	29.946	75.5	68	05.5	73.4	85.3	63.0	74.5		ESE	Fine—light clouds and wind throughout the day. Evening, Lightly overcast—light wind.
F 19	29.996	29.992	74.0	29.972	29.966	74.5	65	06.0	70.4	70.6	67.2	86.0		WSW	Overcast—lt. wind throughout the day. Ev. Moonlight—lt. clouds.
S 20	30.058	30.052	72.0	30.074	30.068	73.0	60	07.0	66.8	69.8	63.0	75.5		WNW v.	Overcast—brisk wind throughout the day. Evening. Fine and moonlight—brisk wind,
●☉ 21	30.058	30.052	70.0	30.014	30.010	72.0	60	06.5	69.8	73.7	62.0	72.2		S	A.M. Heavy clouds—brisk wind. P.M. Fine—light clouds—brisk wind. Evening, Fine—light clouds and wind.
M 22	30.012	30.006	72.0	29.984	29.980	72.0	59	09.0	70.0	77.0	60.5	74.5		NNE	Fine—lt. clouds & wind throughout the day. Ev. Fine & moonlight.
T 23	29.966	29.960	73.0	29.838	29.834	73.0	64	05.0	72.0	75.5	65.0	79.0		S	A.M. Light fog and wind. P.M. Fine—light clouds—brisk wind. Evening, Fine and moonlight.
W 24	29.900	29.896	69.0	29.810	29.804	71.0	56	05.5	62.8	74.0	59.5	80.0		SW	A.M. Thick fog—light wind. P.M. Fine—light clouds and wind. Evening, Overcast—rain, with vivid lightning.
T 25	29.760	29.754	67.0	29.750	29.744	69.0	61	02.0	61.5	69.0	57.5	74.5	.166	NE	Overcast—brisk wind with showers throughout the day. Ev. Overcast—very heavy rain with lightning, with high wind.
F 26	29.890	29.886	69.0	29.884	29.880	70.0	63	05.5	68.0	73.0	61.0	70.5	.369	ENE	A.M. Lightly ovct.—lt. wind. P.M. Fine—lt. clds. & wind. Ev. Same.
S 27	30.008	30.004	67.0	29.980	29.974	69.0	61	04.0	63.0	70.8	60.0	74.0		N	A.M. Overcast—brisk wind. P.M. Fine—lt. clouds—brisk wind. Evening, The same.
☉ 28	30.046	30.040	67.0	30.032	30.026	69.0	61	02.0	62.0	69.5	61.0	71.5	.127	N	A.M. Overcast. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
M 29	30.028	30.022	66.0	29.996	29.992	69.0	63	01.0	63.0	71.0	60.0	70.5	.283	NNE	A.M. Ovct.—lt. wind. P.M. Fine—lt. clds. & wind. Ev. Tremendous heavy rain between 4 and 6 P.M., with lightning & thunder—brisk wind.
T 30	30.076	30.070	66.5	30.048	30.044	68.0	61	02.0	63.0	67.4	60.0	72.0	1.827*	NW	Overcast—lt. wind throughout the day. Ev. The same.
W 31	30.202	30.198	66.0	30.208	30.202	65.0	48	06.5	56.5	61.5	50.0	69.0		N	A.M. Lightly overcast—light wind. P.M. Fine—light clouds and wind. Evening, Lightly overcast.
MEAN.	30.079	30.074	70.3	30.043	30.038	70.9	60	05.7	67.0	73.8	60.8	76.0	Sum. 3.800		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.971 .. 29.934 C. 29.965 .. 29.928

The Observations for August were not taken by the Assistant Secretary on account of absence.
* One of the heaviest showers, within the space of two hours, on the Royal Society's records.

METEOROLOGICAL JOURNAL FOR SEPTEMBER AND OCTOBER, 1842.

1842.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M. deg. Fahr.	Diff. of Wet and Dry Bulb Thermometer.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering Lowest	External Thermometers. Self-registering Highest	Rain in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
SEPTEMBER															
T 1	30.034	30.028	62.0	*Omitted*	*Omitted*	*Omit.*	57	00.5	58.5	*Omit.*	55.0	62.0	.166	S	Overcast—light wind and rain throughout the day. Ev. The same.
F 2	30.170	30.162	65.3	30.188	30.180	67.7	64	05.5	68.7	74.2	58.0	70.3	.311	NNW	A.M. Cloudy—light breeze. P.M. Fine—light clouds and breeze. Evening, Fine and starlight.
S 3	30.286	30.278	66.2	30.252	30.244	68.5	63	04.6	62.5	69.2	60.4	76.0		NW	A.M. Overcast—light breeze. P.M. Fine—light clouds. Evening, Fine and starlight.
○⊙ 4	30.274	30.266	65.7	30.262	30.256	68.0	62	05.1	61.3	68.7	57.3	70.6		SW	Ditto ditto ditto.
M 5	30.268	30.260	65.0	30.172	30.164	67.7	61	06.5	63.7	68.8	56.4	70.2		SE	Fine—light clouds and breeze throughout the day. Ev. Fine and starlight.
T 6	30.008	30.000	66.0	29.968	29.960	67.3	60	07.1	64.0	69.3	57.6	71.3		SSE	A.M. Cloudy—light breeze. P.M. Fine—lt. clouds. Evening, Fine and starlight.
W 7	29.928	29.920	68.2	29.776	29.768	67.0	59	06.3	62.0	66.7	54.8	70.8		E	A.M. Fine—lt. clouds. P.M. Cloudy—lt. wind. Ev. Thunder and lightning, accompanied with very heavy rain.
T 8	29.466	29.458	70.0	29.514	29.506	64.7	62	07.8	63.4	56.7	60.3	70.4	.383	S	A.M. Fine—light clouds—high wind, as also high wind throughout the night. P.M. Ovct.—lt. rain—h. wind. Ev. Fine & starlight.
F 9	29.574	29.568	62.0	29.510	29.502	64.8	59	06.0	61.7	63.8	54.6	66.6	.594	S	Overcast—brisk wind throughout the day, with occasional lt. rain. Evening, early part, Overcast; after, Fine and starlight.
S 10	29.458	29.452	68.0	29.550	29.544	64.5	59	06.0	60.7	59.8	56.3	67.4	.022	SW var.	A.M. Fine—lt. clds. & wind. P.M. Cldy. with slt. rain. Ev. The same.
⊙11	29.720	29.714	65.7	29.700	29.696	63.2	57	06.1	59.9	63.8	52.7	65.0	.052	W	Fine—light clouds and wind throughout the day. Ev. Fine & starlight.
M12	29.844	29.836	61.8	29.882	29.874	63.6	57	06.6	60.3	63.8	56.2	65.3		NW	Ditto ditto ditto.
T13	30.144	30.136	66.0	30.152	30.144	63.9	58	04.4	59.0	63.8	52.4	66.4		N	A.M. Fine—light clouds and wind. P.M. Cloudy—light wind. Evening, Fine and starlight.
W14	30.234	30.226	62.0	30.206	30.198	63.8	59	03.9	62.0	67.8	55.0	66.6		N	Fine—lt. clouds & wind throughout the day. Ev. Fine and moonlight.
T15	30.216	30.208	62.3	30.154	30.146	64.5	60	03.1	61.5	67.0	57.2	70.0		N	A.M. Cloudy—light fog and wind. P.M. Fine—nearly cloudless. Evening, Fine and moonlight.
F16	30.150	30.146	61.6	30.076	30.070	63.9	59	04.4	58.3	66.7	54.8	69.3		E	A.M. Light fog & wind. P.M. Cloudy—light wind. Ev. The same.
S17	29.852	29.846	66.3	29.790	29.782	64.8	60	06.3	65.7	68.7	56.2	68.3		E	Fine—light clouds & wind throughout the day. Ev. Overcast—lt. rain.
⊙18	29.810	29.802	62.0	29.750	29.744	63.0	59	04.7	56.5	58.0	54.4	71.0	.261	N	Overcast—light rain and wind throughout the day. Ev. The same.
●M19	29.644	29.638	61.7	29.628	29.620	63.0	59	05.5	61.0	60.3	52.4	65.4	.205	S	A.M. Fine—light clouds and wind. P.M. Dark heavy clouds—brisk wind—light rain. Evening, Fine and moonlight.
T20	29.570	29.564	63.0	29.534	29.526	61.7	55	05.8	58.7	56.3	50.6	65.4	.033	SW	A.M. Fine—light clouds and wind. P.M. Cloudy, with occasional slight rain. Evening, Fine and moonlight.
W21	29.534	29.526	62.0	29.540	29.534	61.3	54	04.5	57.7	60.2	49.7	64.3	.063	SSW	A.M. Fine—light clouds and wind. P.M. Cloudy—slight rain and wind. Evening, Fine and moonlight.
T22	29.528	29.520	57.2	29.496	29.488	59.2	52	03.3	49.8	57.7	44.4	62.2		W	A.M. Overcast—light wind. P.M. Fine—lt. clds. & wind. Ev. Ovct.
F23	29.534	29.526	58.4	29.480	29.472	58.0	51	03.7	52.3	54.7	46.7	59.7		S	Overcast—lt. rain & wind nearly the whole of the day. Ev. The same.
S24	29.400	29.392	57.0	29.426	29.413	57.2	53	04.1	52.4	54.3	48.6	58.4	.630	E	A.M. Dark heavy clouds—lt. wind. P.M. Ovct—slt. rain. Ev. Ditto.
⊙25	29.580	29.572	56.4	29.616	29.610	58.5	54	03.0	55.7	61.0	46.6	57.3	.111	N	A.M. Light fog and wind. P.M. Fine—light clouds and wind. Evening, Overcast—light rain.
M26	29.866	29.858	58.0	29.902	29.896	59.2	55	03.2	57.0	59.3	52.6	62.7	.338	N	A.M. Fine—lt. clouds & wind—heavy shower early. P.M. Cloudy—lt. wind. Evening, Dark heavy clouds—moon very bright.
T27	29.934	29.926	55.6	29.896	29.890	55.9	50	03.3	52.2	51.7	50.5	62.0	.088	NNE	Overcast—light rain—brisk wind nearly throughout the day. Ev. Overcast—brisk wind.
W28	30.110	30.102	56.0	30.098	30.090	56.3	50	03.9	52.7	55.7	50.0	54.8	.288	N	A.M. Overcast—brisk wind. P.M. Fine—lt. clds.—brisk wind. Ev. Moonlight—dark clouds.
T29	30.080	30.072	55.2	30.086	30.078	55.8	49	05.0	53.5	53.5	49.6	58.7		NE var.	A.M. Fine—light clouds—brisk wind. P.M. Cloudy—brisk wind—slight rain. Evening, Cloudy.
F30	30.208	30.200	54.4	30.184	30.176	54.5	47	05.6	52.3	53.5	47.5	59.3		NE	A.M. Cloudy—brisk wind. P.M. Fine—nearly cloudless. Ev. Overcast—slight rain.
MEAN.	29.881	29.873	62.0	29.855	29.849	66.3	57	04.9	58.8	61.9	53.5	65.6	Sum. 3.545		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.796 .. 29.759; C. 29.787 .. 29.752
OCTOBER															
S 1	30.268	30.262	54.0	30.280	30.272	55.0	48	03.7	50.7	58.0	46.8	56.5		NW	A.M. Fine—light clouds and wind. P.M. Cloudy—light wind. Evening, Overcast—light fog.
⊙ 2	30.336	30.328	52.0	30.252	30.246	53.5	46	03.1	46.2	55.2	42.8	57.6		NNW	A.M. Light fog and wind. P.M. Slightly overcast—light wind. Evening, Fine and starlight.
M 3	30.106	30.098	51.5	30.042	30.034	54.2	47	03.6	50.2	57.7	45.8	56.7		NNW	A.M. Light fog & wind. P.M. Cloudy—light wind. Ev. Overcast.
○T 4	30.096	30.092	52.5	30.098	30.092	53.7	46	04.7	50.3	54.3	45.2	59.4		NNW	A.M. Fine—light clouds and wind—light fog early. P.M. Cloudy—light wind. Evening, Fine and starlight.
W 5	30.236	30.228	50.0	30.230	30.222	51.3	43	02.7	43.3	51.8	42.3	56.0		NNW	A.M. Light fog & wind. P.M. Fine—nearly cloudless. Evening, Starlight—light fog.
T 6	30.334	30.326	49.8	30.302	30.294	52.3	42	03.5	46.0	57.2	42.7	48.3		NW	A.M. Light fog & wind. P.M. Cloudy—lt. wind. Ev. Light fog—few stars.
F 7	30.314	30.306	52.3	30.284	30.276	53.7	47	04.3	51.4	58.8	46.8	59.3		W	A.M. Fine—light clouds and wind. P.M. Cloudy—light wind. Evening, Fine and starlight.
S 8	30.416	30.408	54.3	30.440	30.432	55.6	50	03.0	53.9	57.7	51.0	60.7		N	A.M. Fine—light clouds and wind. P.M. Cloudy—slight rain and wind. Evening. The same.
⊙ 9	30.540	30.532	53.3	30.500	30.494	55.0	48	02.0	51.3	56.5	48.5	50.2		N	Overcast—light wind throughout the day. Evening, The same.
M10	30.510	30.502	54.0	30.468	30.460	55.0	48	04.6	53.7	55.2	51.0	58.2		N	Cloudy—light wind throughout the day. Ev. Fine and starlight.
T11	30.410	30.402	53.2	30.346	30.338	54.3	46	02.5	47.8	57.8	46.3	56.3		NNW	Fine—light clouds and fog throughout the day. Ev. Fine & starlight.
W12	30.332	30.324	54.6	30.278	30.270	55.7	49	03.4	52.4	54.7	48.3	59.6		NNW	A.M. Fine—nearly cloudless—light wind. P.M. Cloudy—light wind. Evening, Overcast—very slight rain.
T13	30.302	30.296	53.7	30.282	30.274	55.0	48	04.2	51.7	54.7	49.2	58.3		N	Overcast—light wind throughout the day. Ev. Overcast—light fog.
F14	30.252	30.246	52.2	30.244	30.236	53.3	47	04.0	48.8	53.4	45.9	56.3		NNW	A.M. Light fog and wind. P.M. Overcast—lt. fog. Ev. The same.
S15	30.312	30.304	52.7	30.286	30.282	53.5	49	02.6	51.0	54.6	49.5	54.7		W	A.M. Thick fog—lt. wind. P.M. Overcast—light wind. Evening, The same—light fog.
⊙16	30.288	30.282	53.2	30.234	30.230	54.6	48	03.5	51.7	55.8	51.3	55.8		W	Overcast—light fog and wind throughout the day. Ev. Light fog.
M17	30.070	30.062	53.0	29.910	29.902	53.8	51	03.3	51.7	52.7	51.0	57.6		NNW	Foggy throughout the day, as also the evening.
T18	29.482	29.476	53.3	29.334	29.328	54.2	48	04.3	52.0	53.0	49.6	54.2		S	A.M. Fine—light clouds and wind. P.M. Cloudy—slight rain and wind. Evening, Overcast—light rain.
●W19	29.280	29.272	50.0	29.428	29.420	51.0	42	02.5	42.3	47.7	40.8	57.8	.488	W	A.M. Overcast—light wind. P.M. Fine—light clouds and wind. Evening, Fine and moonlight.
T20	29.672	29.664	45.6	29.686	29.678	47.0	38	03.0	37.3	45.0	36.6	48.2		W	Fine—nearly cloudless—light wind throughout the day. Ev. Fine and moonlight.
F21	29.912	29.904	43.8	29.948	29.940	44.8	33	03.5	38.0	44.8	34.3	47.0		NW	Fine—lt. clouds & wind throughout the day. Ev. Fine & starlight.
S22	29.700	29.692	41.9	29.238	29.230	43.5	36	03.4	40.0	46.3	32.7	45.7		S	A.M. Overcast—light wind. P.M. Overcast—light rain—high wind. Evening, The same.
⊙23	28.792	28.788	44.3	28.818	28.814	46.0	40	01.5	44.7	47.0	39.7	48.8	.444	S	A.M. Fine—lt. clouds & wind—rain early. P.M. Ovct.—lt. shower. Ev. Overcast.
M24	29.194	29.186	44.0	29.390	29.384	45.7	39	02.8	42.3	45.3	37.5	50.6		W	A.M. Overcast—light fog and wind—slight rain. P.M. Cloudy—light wind. Evening, Fine and moonlight.
T25	29.634	29.626	42.4	29.486	29.480	44.3	37	03.4	41.3	46.5	35.7	46.7	.013	SSE	Overcast—light rain—fog and wind nearly the whole of the day. Evening, The same.
W26	29.590	29.582	43.0	29.634	29.626	54.5	38	03.3	37.8	44.0	34.0	49.0	.344	S	A.M. Fine—light clouds & wind—high wind throughout the night. P.M. Fine—lt. clouds. Ev. Fine and starlight.
T27	29.700	29.692	43.0	29.712	29.704	45.0	38	02.2	42.4	49.4	38.3	45.3		S	A.M. Fine—lt. clds. & wind. P.M. Fine—lt. clouds—slight rain. Ev. Lt. fog.
F28	29.552	29.546	44.0	29.636	29.630	45.9	39	01.6	40.5	48.8	40.0	51.0		W	Fine—lt. clouds & wind throughout the day. Ev. Starlight—lt. fog.
S29	29.806	29.798	43.0	29.866	29.858	44.8	36	01.6	37.3	47.8	35.2	50.6		SSW	Fine—lt. clouds & fog throughout the day. Ev. Starlight—lt. fog.
⊙30	30.116	30.108	42.8	30.150	30.144	44.0	36	01.7	37.4	48.0	34.8	49.0		SW	Fine—light clouds throughout the day—fog early. Evening, Starlight—light fog.
M31	30.268	30.260	45.0	30.262	30.254	47.3	40	03.1	47.7	51.8	37.6	49.7		S	A.M. Light fog & wind. P.M. Overcast. Evening, Fine & starlight.
MEAN.	29.994	29.987	49.1	29.970	29.963	50.9	43	03.1	46.2	52.0	42.9	53.4	Sum. 1.289		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.943 .. 29.914; C. 29.935 .. 29.906

1842.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M., deg. Fahr.	Diff. of Wet and Dry Bulb Ther.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering. Lowest	External Thermometers. Self-registering. Highest	Rain in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
NOVEMBER															
T 1	30.[illegible]34	30.226	47.0	30.[illegible]72	30.164	47.8	43	01.7	44.9	51.3	43.2	53.4		SSW	A.M. Fine—light clouds and wind. P.M. Fine—nearly cloudless. Evening, Light fog.
○ W 2	30.140	30.132	47.4	30.096	30.088	48.8	45	01.3	48.3	50.8	43.8	52.6		E	Overcast—deposition—light wind throughout the day. Evening, Fine and starlight—light fog.
T 3	30.000	29.994	46.7	29.956	29.948	47.7	42	02.2	43.3	47.4	42.0	52.0		N	A.M. Overcast—brisk wind. P.M. Cloudy—lt. wind. Ev. Overcast —slight rain.
F 4	30.060	30.052	44.8	30.126	30.120	45.0	38	01.8	39.5	38.8	37.8	49.0		NNW	A.M. Fine—light clouds and wind. P.M. Cloudy—light rain and snow. Evening, Cloudy—light fog.
S 5	30.190	30.182	43.0	30.120	30.112	44.4	37	03.5	42.0	45.4	37.4	43.4	.033	N	A.M. Fine—light clouds and wind—light rain early. P.M. Cloudy—light wind. Evening, Overcast—very slight rain.
☉ 6	30.202	30 194	41.8	30.158	30.150	43 0	36	02.2	38.3	42.3	36.7	46.8		N	Cloudy—lt. wind throughout the day. Ev. The same, with light fog.
M 7	30.130	30.122	42.7	30.128	30.120	44.6	39	02.7	42.3	45.6	38.4	43.6		NW	A.M. Cloudy—brisk wind—slight rain early. P.M. Cloudy—brisk wind—slight rain. Evening, Light fog.
T 8	30.152	30.144	43.6	30.0[illegible]8	30.070	44.4	39	02.3	42.3	44.3	40.6	48.2		NW	Cloudy—brisk wind throughout the day. Ev. Overcast—light fog.
W 9	29.806	29.798	44.0	29.700	29.692	45 2	37	03.8	43.7	45.5	41.8	45.7		S	Cloudy—high wind throughout the day. Ev. Ovct.—lt. rain—h. wind.
T 10	29.684	29.676	46.6	29.636	29.628	48.0	45	01.7	48.4	49.7	44.0	49.8	.038	S	Overcast—brisk wind throughout the day—very high wind throughout the night. Evening, The like.
F 11	29.180	29.172	47.2	29.002	28.998	49.4	45	02.8	50.7	51.7	43.2	52.3	.019	S	A.M. Cloudy—high wind—light rain early—very high wind throughout the night. P.M. Ovct.—lt. rain—high wind. Ev. Overcast.
S 12	29.122	29.116	50.6	29.332	29.326	51.6	48	01.6	51.5	53.8	49.5	55.0	.261	W	A.M. Cloudy—high wind—light rain—very high wind throughout the night. P.M. Cloudy—high wind. Ev. Fine and starlight.
☉ 13	29.512	29.506	50.6	29.256	29.248	51.3	47	01.9	50.0	52.3	48.0	55.5	.494	SSE	Ovct.—lt. rain—high wind nearly the whole of the day. Ev. The same.
M 14	29.720	29.714	50.6	29.804	29.798	51.3	47	02.2	47.7	47.7	46.7	55.0	.266	W	A.M. Light fog and wind. P.M. Fine—light clouds. Ev. Overcast—light rain—high wind.
T 15	29.686	29.680	48.8	29.618	29.612	48.3	45	00.2	43.3	44.5	43.7	51.6	.625	E	Overcast—rain, with lt. wind nearly the whole day. Ev. The same.
W 16	29.762	29.754	47.8	29.790	29.782	47.7	43	00.6	44.0	44.3	43.6	47.0	.355	NE	Overcast—high wind, with occasional rain throughout the day. Evening, Fine and starlight.
T 17	30.232	30.224	44.0	30.360	30.352	44.6	37	03.5	40.7	43.7	39.2	45.3	.033	NNE	Ovct.—brisk wind throughout the day. Ev. Moonlight—lt. clouds.
● F 18	30.582	30.574	44.2	30.532	30.526	45.0	37	03.7	41.3	43.3	40.2	45.0		E	A.M. Light fog and wind. P.M. Fine—light clouds. Evening, Fine and moonlight—light clouds.
S 19	30.232	30.224	43.3	30.060	30.052	44.7	41	04.0	43.8	47.3	38.4	45.3		S	A.M. Overcast—very slight rain—high wind. P.M. Overcast—light wind. Evening, Overcast—light rain and wind.
☉ 20	29.788	29.780	47.2	29.774	29.768	48.0	44	02.4	46.7	47.0	37.8	52.8	.677	N	Overcast—brisk wind throughout the day. Ev. The same—lt. fog.
M 21	29.800	29 794	44.8	29.824	29.816	45.2	38	02.5	40.3	43.7	40.3	49.6		N	Fine—lt. clouds and wind throughout the day. Ev. Overcast—lt. fog.
T 22	29.420	29.412	42.9	29.284	29.278	42.7	37	01.2	35.7	37.0	36.4	45.3	.244	SE	Overcast—light wind, rain, and snow nearly the whole of the day. Evening, Fine and starlight.
W 23	29.496	29.488	41.0	29.590	29.584	42.4	37	01.4	38.4	43.7	35.6	39.4	.177	S	A.M. Fine—lt. clouds & wind. P.M. Cloudy—lt. rain. Ev. Ovct.—light rain and wind.
T 24	28.908	28.900	43.6	28.916	28.908	45.2	40	02.0	43.7	47.0	38.7	46.3	.105	S	A.M. Fine—light clouds and wind. P.M. The same, with light shower. Evening, Overcast—heavy rain—high wind.
F 25	28.900	28.896	45.0	28.878	28.872	46.0	42	02.5	44.2	46.3	42.8	48.2	.300	S var.	A.M. Cloudy—light rain—very high wind, as also throughout the night. P.M. Fine—lt. clouds & wind. Ev. Overcast—brisk wind.
S 26	29.094	29.088	41.5	29.170	29.164	45.6	40	03.2	43.4	47.6	41.3	47.6	.105	SSE	Fine—lt. clouds & wind throughout the day. Ev. Fine & starlight.
☉ 27	29.366	29.358	44.2	29.314	29.306	45.0	40	01.8	42.7	45.8	40.2	49.0		S	A.M. Overcast—slight rain and wind. P.M. Fine—light clouds and wind. Evening, Light fog and rain.
M 28	28.944	28.938	46.3	28.892	28.886	48.3	45	02.7	49.3	52.3	43.0	50.8	.222	SE	A.M. Fine—light clouds and wind—light rain early. P.M. Cloudy—light wind. Evening, Fine and starlight.
T 29	29.540	29.532	47.0	29.546	29.540	48.0	42	01.9	44.4	48.4	44.2	54.3	.061	SE	Fine—light clouds and wind nearly the whole of the day. Evening, Overcast—light fog.
W 30	29.662	29.654	47.2	29.860	29.852	48.0	44	01.3	46.2	47.3	44.6	51.2	.033	W	A.M. Light fog—rain early. P.M. Fine—lt. clouds. Ev. Light fog.
MEAN.	29.718	29.711	45.6	29.699	29.692	46.6	41	02.3	44.0	46.5	41.4	49.0	Sum. 4.048		Mean Barometer corrected .... 9 A.M. F. 29.676, C. 29.668; 3 P.M. F. 29.655, C. 29.647
DECEMBER															
T 1	30.062	30.054	47.8	30.036	30.030	49.5	46	01.3	49.7	51.5	43.3	51.0		SE	A.M. Cloudy—very slight rain—brisk wind. P.M. Overcast—brisk wind. Evening, The same.
○ F 2	30.110	30.102	51.6	30.108	30.100	52.9	49	02.2	52.0	54.3	49.8	55.0		SSE	A.M. Overcast—very slight rain—brisk wind—high wind throughout the night. P.M. Cloudy. Evening, Fine and starlight.
S 3	30.252	30.246	50.0	30.318	30 310	51.0	46	02.0	46.7	52.8	45.5	56.3		S	A.M. Fine—light clouds and wind. P.M. Cloudy—deposition—light wind. Evening, Thick fog.
☉ 4	30.454	30.446	50.0	30.406	30.398	51.0	47	01.3	47.7	50.7	44.4	54.7		W	A.M. Lt. fog & wind. P.M. Cloudy—lt. wind. Ev. Lt. fog & wind.
M 5	30.344	30.336	49.4	30.286	30.280	50.2	44	01.5	44.7	49.3	44.6	52.6		SSW	A.M. Lightly ovct.—lt. wind. P.M. Cldy.—lt. wind. Ev. Thick fog.
T 6	30.264	30.256	47.8	30.226	30.218	47.4	43	01.3	41.3	41.3	40.8	50.6		SSE	A.M. Overcast—deposition—lt. fog. P.M. Thick fog. Ev. The same.
W 7	30.350	30.342	45.2	30.352	30.344	45.0	38	01.6	39.5	40.3	37.8	42.8		W	Light fog and wind throughout the day. Evening, The same.
T 8	30.442	30.434	43.6	30.422	30.416	43.7	39	01.4	37.3	39.8	36.0	41.6		W	Thick fog—light wind nearly the whole of the day. Evening, Starlight—light fog.
F 9	30.424	30.418	43.8	30.372	30.364	44.6	40	02.1	41.7	43.7	36.6	43.2		W	A.M. Light fog and wind. P.M. Overcast—lt. wind. Ev. Light fog.
S 10	30.256	30.250	43.8	30.212	30.204	43.6	38	02.1	37.8	38.8	37.5	45.0		SE	Cloudy—light wind throughout the day. Evening, Lightly overcast.
☉ 11	30.026	30.018	42.3	29.956	29.950	43.0	38	01.0	38.7	42.4	37.3	40.8		E	Overcast—lt. wind throughout the day. Ev. Overcast—slight rain.
M 12	29.820	29.814	45.0	29.906	29.900	48.2	43	02.4	50.3	54.4	38.8	51.5	.269	SE	Overcast—slight rain—brisk wind nearly the whole of the day. Evening, Overcast.
T 13	30.076	30.070	51.3	30.066	30.058	52.0	48	02.0	51.6	54.8	38.8	56.5		SE	A.M. Fine—light clouds. P.M. Fine—nearly cloudless—light wind. Evening, Fine and starlight—light clouds.
W 14	30.144	30.136	51.3	30.134	30.126	52.0	48	01.4	49.8	53.7	49.2	57.5		S	A.M. Lightly overcast—light wind. P.M. Fine—light clouds. Evening, Fine and starlight.
T 15	30.164	30.156	50.2	30.160	30.152	51.5	46	02.3	48.3	52.8	46.8	55.0		S	Fine—light clouds and wind throughout the day. Evening, Cloudy.
F 16	30.090	30.082	51.3	30.014	30.006	52.3	48	02.6	50.0	53.8	47.7	54.6		S	Overcast—light wind throughout the day. Ev. Cloudy—slight rain.
● S 17	30.002	29.994	52.3	30.110	30.102	52.6	48	02.5	50.5	48.4	50.2	55.6	.050	SSW	Fine—light clouds and wind throughout the day. Evening, Fine and moonlight—light clouds.
☉ 18	30.314	30.306	47.8	30.332	30.328	48.0	42	01.2	39.4	46.3	39.3	52.6		S	Fine—light clouds and wind throughout the day. Evening, Fine and moonlight.
M 19	30.518	30.512	45.6	30.514	30.506	46.0	40	00.8	39.3	44.3	39.0	46.0		W	A.M. Overcast—light fog. P.M. Fine—light clouds. Ev. Cloudy.
T 20	30.430	30.422	45.3	30.400	30.392	46.6	43	01.4	45.7	50.2	39.0	46.4		S	Overcast—deposition—lt. wind throughout the day. Ev. The same.
W 21	30.328	30.320	49.3	30.320	30.312	50.5	46	00.8	51.3	53.0	39.0	51.4		W	Overcast—lt. wind throughout the day. Ev. Overcast—deposition.
T 22	30.194	30.186	51.5	30.068	30.060	51.8	46	01.2	50.2	51.7	49.0	56.3		S	A.M. Fine—light clouds and wind. P.M. Fine—nearly cloudless. Evening, Overcast.
F 23	29.636	29.630	51.3	29.586	29.580	51.3	48	01.5	47.4	46.4	47.6	53.8	.075	S	A.M. Overcast—slight rain. P.M. Overcast—deposition. Ev. Fine and starlight.
S 24	29.696	29.690	45 8	29.722	29.714	45.7	39	01.6	36.7	41.7	36.2	47.4	.097	S	A.M. Fine—nearly cloudless—light wind and frost. P.M. Fine—nearly cloudless. Evening, Fine and starlight.
☉ 25	29.848	29.842	42.0	29.742	29.738	44.0	37	01.7	36.7	46.3	35.0	42.4		S	A.M. Fine—nearly cloudless—light wind and frost. P.M. Overcast—lt. wind. Ev. Overcast—very fine rain—high wind.
M 26	29.566	29.560	46.7	29.428	29.422	48.0	45	02.0	48.8	48.7	37.3	50.3	.022	S var.	A.M. Overcast—high wind, as also during the night. P.M. The same, with slight rain. Evening, The same.
T 27	29.364	29.356	47.5	29.482	29.476	48.0	43	01.6	43.7	45.7	44.0	50.6	.161	S	A.M. Ovct.—lt. rain & wind. P.M. Fine—lt. clds. Ev. Starlight—lt. fog.
W 28	30.030	30.024	42.8	30.126	30.118	43.0	36	01.4	35.0	41.3	34.7	47.0		W	A.M. Fine—light clouds—fog and wind. P.M. Fine—nearly cloudless. Evening, Fine and starlight.
T 29	30.152	30.146	43.0	30.152	30.144	44.7	42	02.2	47.0	50.7	35.4	48.2		SW	Overcast—light brisk wind nearly the whole of the day; early part, very slight rain. Evening, Overcast.
F 30	30.222	30.216	47.4	30.212	30.206	49.4	45	02.5	52.3	54.3	47 2	53.3		S var.	Cloudy—light wind throughout the day. Evening, Overcast.
○ S 31	30.144	30.140	50.3	30.046	30.040	51.3	47	01.9	51.3	54.3	50.6	55.4		S var.	Cloudy—brisk wind throughout the day. Evening, Early part, slight rain; after, fine and starlight.
MEAN.	30.120	30.113	47.5	30.103	30.097	48.4	44	01.7	45.2	48.3	41.9	50.5	Sum. .674		Mean Barometer corrected .... 9 A.M. F. 30.073, C. 30.065; 3 P.M. F. 30.053, C. 30.047

PHILOSOPHICAL TRANSACTIONS.

VIII. *On the Gas Voltaic Battery.—Experiments made with a view of ascertaining the rationale of its action and its application to Eudiometry.*

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Received March 27,—Read May 11, 1843.

In the Philosophical Magazine for December 1842, I have published an account of a voltaic battery in which the active ingredients were gases, and by which the decomposition of water was effected by means of its composition.

The battery described in that paper consisted of a series of tubes containing strips of platinum foil covered with a pulverulent deposit of the same metal; the platinum passed through the upper parts of the tubes, which were closed with cement, the lower extremities were open; they were arranged in pairs in separate vessels of dilute sulphuric acid, and of each pair one tube was charged with oxygen, the other with hydrogen gas, in quantities such as would allow the platinum to touch the dilute acid; the platinum in the oxygen of one pair was metallically connected with the platinum in the hydrogen of the next, and a voltaic series of fifty pairs was thus formed. With this battery the following effects were produced:—

1st. A shock was given which could be felt by five persons joining hands.

2nd. The needle of a moderately sensitive galvanometer was whirled round and remained permanently deflected 60°.

3rd. A gold-leaf electroscope was notably affected.

4th. A brilliant spark visible in broad day-light was given between charcoal points.

5th. Iodide of potassium, hydrochloric acid, and water acidulated with sulphuric acid were severally decomposed; the gas from the decomposed water was collected and detonated. The gases were evolved in the direction which the chemical theory would indicate, the hydrogen travelling in one direction throughout the circuit, and the oxygen in the reverse.

When distilled was substituted for acidulated water in the battery cells, the effects were similar but more feeble.

The effects, though clear and decisive in themselves, were further tested by counter experiments, such as reversing the current by reversing the gases, &c.; but these I need not here detail, as the electrical effects of the gas battery, when charged with oxygen and hydrogen, have since the publication of that paper been repeatedly verified. I further stated, that when carbonic acid and nitrogen were substituted for oxygen and hydrogen, no voltaic effects were produced; that oxygen and nitrogen produced no effects, but that hydrogen and nitrogen did produce a voltaic current, which I attributed to the combination, with the hydrogen, of the oxygen of atmospheric air in solution; this opinion will be further tested in the following paper.

The voltaic current generated by this battery I attributed to chemical synthesis, of an equal but opposite kind, in the alternate tubes, at the points where the liquid, gas, and platinum met, and the object of covering the platinum with the pulverulent deposit*, was to increase the number of these points, the liquid being retained upon the surface of the platinum by capillary attraction.

The point which appeared to me at that time as most important, was the beautiful instance of the correlation of natural forces exhibited by the fifth effect, in which gases by combining and becoming a liquid, transfer a force which is capable of decomposing a similar liquid, and causing its constituents to become gases; heat, chemical action and electricity being all blended and mutually dependent.

The apparatus with which I made the above experiments being composed of some pieces of tubing which happened to be in my laboratory, did not enable me to attain any precise accuracy of measure as to the volumes of gases absorbed, or to prove that Faraday's law of definite electrolysis finds no exception in the gas battery. Since that paper was written I have, after some failures, constructed apparatus by which I have been enabled to verify this law and to extend my researches into the nature of gaseous voltaic action. I have felt the more called on to multiply experiments on this subject, as a letter has been published on the gas battery, written by an electrochemist for whose opinion I have much respect, which attributes its action to a cause different from that to which I assigned it.

Soon after my original publication I received a letter from Dr. Schœnbein, the substance of which has since appeared in print†. Dr. Schœnbein there expresses an opinion, that in the gas battery oxygen does not immediately contribute to the production of the current, but that it is produced by the combination of hydrogen with water. I have recently heard a similar opinion to that of Dr. Schœnbein expressed by other philosophers, but I must take the liberty of dissenting from it and of adhering to that which I expressed in my original paper. My grounds of dissent will be seen in some of the ensuing pages.

In describing the apparatus used in the following experiments, I shall mention three forms of gas battery, with the first two of which my experiments were all performed;

* For the method of effecting this see Mr. Smee's paper, Philosophical Magazine, April 1840.

† Philosophical Magazine, March 1843, p. 105.

Fig. 1.

Fig. 2.

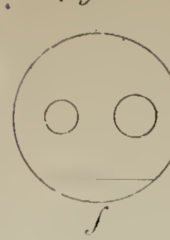


Fig. 3.

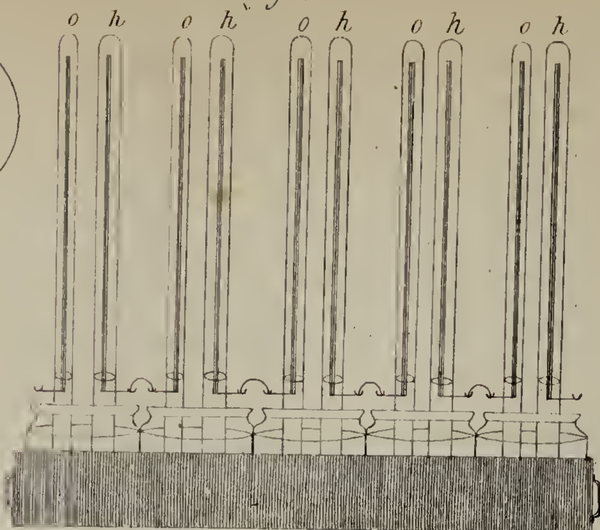


Fig. 4.

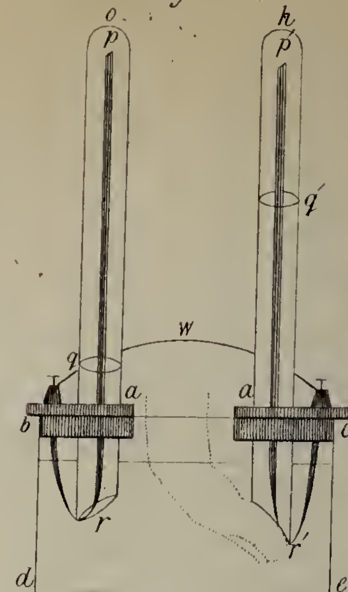


Fig. 5.

Fig. 6

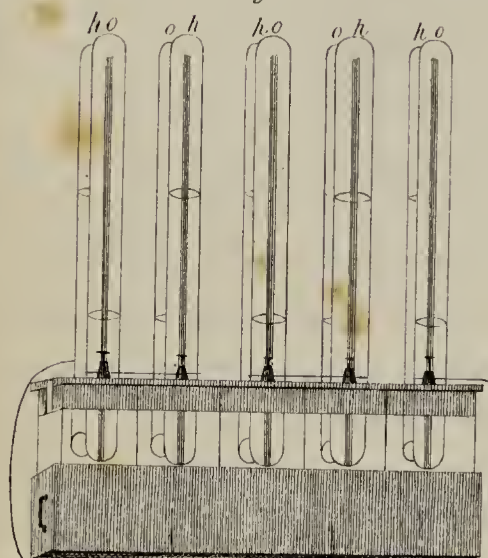


Fig. 7.

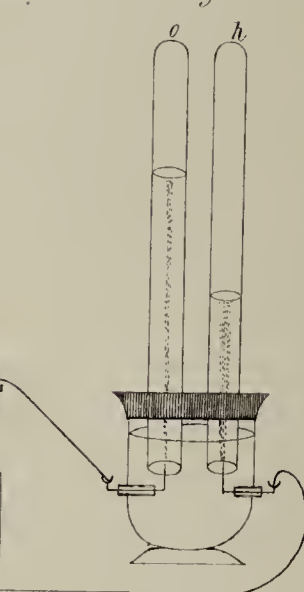


Fig. 8.

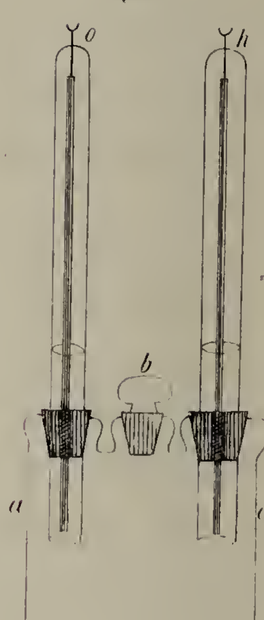


Fig. 9

Fig. 10.

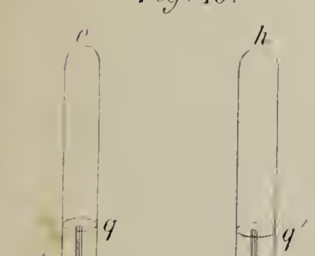


Fig. 11.

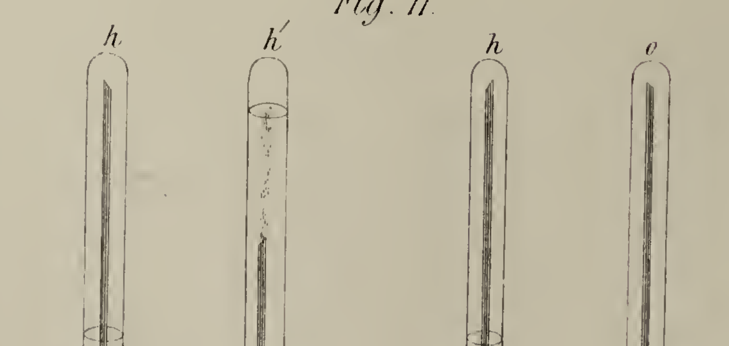
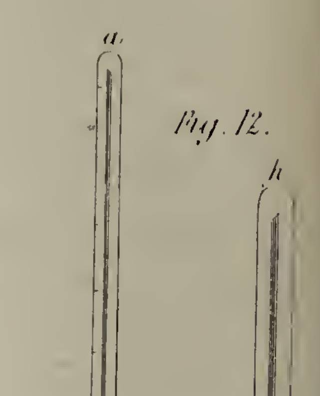


Fig. 12.



J. Basire

the latter has only occurred to me while writing this paper. I have, therefore, not yet had an opportunity of trying it*, but it appears to me by far the best of the three, though, doubtless, superior modifications will shortly be discovered. Plate V. fig. 1 represents one of these forms; *a, b, c, d* is a wide-mouthed glass jar, into which a wooden plug, *a, b,* fits tightly by means of attached pieces of cork; this wooden cover is perforated to receive the tubes *o, h,* of which the size is such that the content of *h* shall be double that of *o*, and which are firmly cemented into it; the wooden cover is shown in plan in fig. 2; the piece *f* is capable of being detached at pleasure, in order to introduce a tube for charging the apparatus with gas; *p r, p′ r′* are strips of well-platinized platinum foil, slightly curved like a cheese scoop to keep them erect and in the centre of the tube, and rivetted or welded to stout platinum wires, which are hermetically sealed into the glass, and terminate in brass mercury cups at *g, g*. This form of battery is charged by inverting it so as to fill the tubes with liquid; on reinversion the tubes may be charged with gas from a crooked tube and bladder. The apparatus (fig. 1.) is represented as charged and ready for use, and in fig. 3 is a battery of five cells, also represented as just charged.

The advantage of this form over that which I shall next describe, is the facility with which the tubes are filled with liquid, and the absence of any necessity of touching the electrolyte with the fingers. On the other hand, its disadvantages are the difficulty of examining the gases after experiment, and the impossibility of doing so during experiment without changing the electrolyte, as in order to examine the gases the whole apparatus must be immersed in a water-trough, and the cover with the attached tubes taken off while the jar and the ends of the tube are under water.

Fig. 4 represents a cell of the second form; *b, c, d, e* is a parallelopiped glass or stoneware vessel, such as is commonly used for the outer cells of the nitric acid batteries; the tubes are cemented into pieces of wood, *a b, a c,* and can with the wood be separately detached from the trough, as shown in fig. 5. At the aperture or space, *a a,* between the tubes there is just room for a finger to enter, close the orifice of either tube, and thus detach it from the apparatus. In this figure the platinum foil is turned up round the edge of the tube, instead of being attached to a wire sealed into the glass, and instead of a mercury cup there is a binding-screw connexion; but it is obvious that this part of the arrangement may be interchanged with the other apparatus, or varied *ad libitum*. This apparatus I have found in practice to be very much more convenient than the former, from the facility of detaching either tube so as to discharge some of the gas, if it be desirable to alter the level of the water-mark; or to examine or change the gas in any of the tubes. On the other hand, it has the disadvantage of requiring the finger to be immersed in the electrolyte, which, when the latter is of an active chemical character, is unpleasant and in some cases injurious. In fig. 6, a battery of five cells of this construction is represented as when charged with oxygen and hydrogen, and having been for some time connected

* See Postscript.

with a voltameter (fig. 7), the tubes of which are of the same size as those of the battery.

In the form last described (figs. 4 and 6), the tubes were all as nearly of the same size as could be procured; they contained each about $1\frac{1}{2}$ cubic inch; in the first form (figs. 1 and 3), the portion *o*, *r* of the narrow tube contained $1\frac{1}{4}$ cubic inch, and the portion *h*, *r′* of the wide tube contained $2\frac{1}{2}$ cubic inches. A portion of the apparatus with which I wrought was constructed by my order for the London Institution, and another portion belonged to Mr. Gassiot, and was by him very kindly placed at my disposal for the purpose of these experiments; had it not been for this valuable addition, I should have been obliged to make all my experiments on a much smaller scale; they would have taken more time and been by no means so satisfactory.

As I have already stated, a third form has occurred to me while writing this paper, which I think in many respects more advantageous than either of the two preceding, and which, as it may be some time before I can experiment with it myself, I will here describe for the benefit of those who are differently situated. One cell of it is shown in fig. 8: *a*, *a*, is a Woulfe's bottle with three necks; in the centre neck is fitted a glass stopper, *b*; in the other two the tubes *o*, *h* fit accurately by means of glass collars (*c c*, fig. 9.) welded to them and ground on the outside; the platinum is hermetically sealed into the tops of the tubes, which may be charged in a similar manner to fig. 1. By immersing this apparatus in the water-trough, each tube with the gas it contains may be detached and examined separately, but its principal advantage is, that by slightly greasing the stopper and collars it may be made perfectly air-tight, which, for reasons that will be apparent in the course of this paper, is a most material point. This apparatus, moreover, being entirely composed of glass and platinum, concentrated acid, alkaline or other corrosive solutions, may be used as the electrolyte, without damaging the apparatus or introducing foreign matter.

In the experiments I am about to describe, the results were generally tested by chemical action, as manifested by the electrolysis, either of iodide of potassium or of water. I had at my disposal a highly sensitive astatic galvanometer, but I found such slight local actions disturb it, that a range of test experiments was in each case necessary to eliminate the true battery action from the accidental currents; and with all the pains that could be bestowed upon it, the results were less definite and trustworthy than those obtained with the iodide.

I may here state also, that, although with the battery described in my original paper when charged with oxygen, hydrogen and dilute sulphuric acid, I could not succeed in perceptibly decomposing water with less than twenty-six cells, yet the new arrangements, from their superiority in size and construction, were capable, when charged with the same gases and electrolyte, of decomposing water with four cells; and a single cell would decompose iodide of potassium.

Experiment 1.—Ten cells charged to a given mark on the tube with dilute sulphuric acid, sp. gr. 1·2, oxygen and hydrogen, were arranged in circuit with an interposed

voltameter*, as in figs. 6 and 7, and allowed to remain so for thirty-six hours. At the end of that time 2·1 cubic inches of mixed gas were evolved in the voltameter; the liquid had risen in each of the hydrogen tubes of the battery to the extent of 1·5 cubic inch, and in the oxygen tubes 0·7 cubic inch, equalling altogether 2·2 cubic inches; there was therefore 0·1 cubic inch more of hydrogen absorbed in the battery tubes than was evolved in the voltameter.

This experiment was several times repeated with the same general results; I give some of them in the annexed Table.

Cubic inch of oxygen absorbed in the battery cells.	Cubic inch of hydrogen absorbed in the battery cells.	Cubic inch of oxygen evolved in voltameter.	Cubic inch of hydrogen evolved in voltameter.	Time.	Number of cells.
0·7	1·4	0·7	1·4	36 hours.	10
0·5	1·2	0·5	1·1		
0·6	1·4	0·6	1·3		
0·6	1·3	0·5	1·2		
0·6	1·4	0·6	1·3		
Mean 0·6	1·34	0·58	1·26		

We may observe generally in these experiments, that the hydrogen evolved in the voltameter is somewhat more than double the volume of the oxygen, and that a still extra quantity of hydrogen is absorbed in the battery. With regard to the excess of hydrogen in the voltameter, this, as is well known to electricians, is always observable in the electrolysis of water, and has been attributed by FARADAY to the more ready solubility of oxygen, and its tendency to form oxygenated water†; but we have in the above experiments a still greater excess of hydrogen absorbed in the battery tubes; this result previous experiments had led me to expect. In one of these I found voltaic action produced by tubes charged alternately with hydrogen and water, and attributed it to the combination of hydrogen with the oxygen of atmospheric air in solution‡. Granting for the moment this explanation to be correct, in a gas battery charged with oxygen and hydrogen we should have, upon completion of the circuit, three distinct voltaic actions:—First, the principal action occasioned by the gases in the tubes reacting upon each other through the medium of the electrolyte, *i. e.* reverting to fig. 4, an action in which the portions of the platinum exposed to the gases $p\ q$, $p'\ q'$, would be the efficient plates. Secondly, an action between the hydrogen at $p'\ q'$ and the air in solution in the neighbourhood of the immersed portion of the plate q, r; this would add to the general current, but would tend disproportionately to diminish the hydrogen. Thirdly, a local action between the hydrogen at p', q' and the air in solution around the part q', r'; this would add nothing to the general cur-

* These experiments were made with the battery fig. 1, though for more clearly showing the volumes of the gases the second form is represented in figures 6 and 7. The voltameter employed on this occasion had electrodes of fine platinum wire a quarter of an inch long. From the nature of the gas battery it is difficult to know the efficient surface of the plates. In ordinary batteries I have found, and stated some time ago, that for quantitative effects, the electrodes should be of the same size as the battery plates.

† Experimental Researches, § 716, 717.

‡ Phil. Mag., Dec. 1842, p. 419, Exp. 11.

rent, but would also tend to diminish the hydrogen. As this last is totally independent of the general action, it could be abstracted by merely placing a cell charged similarly to the battery out of the circuit with the terminals unconnected as in fig. 1; in a cell so placed the hydrogen was found to be absorbed in the ratio of rather less than 0·1 cubic inch in twenty-four hours.

On some occasions I found the rise of liquid in the hydrogen cell to be unequal in different tubes of the battery, and this I found more particularly the case in the battery fig. 4; it was some time before I discovered the cause of this. I will not enumerate my different conjectures, but state that which proved to be the correct one. As, in using the two forms of batteries (figs. 1 and 4), the chief difference consisted in the introduction of the finger, it occurred to me that my assistant's hands, which were employed in various manipulations, might, in placing the tubes in the cells of fig. 4, introduce into the electrolyte small portions of foreign matter, particularly metals, and that thus a local action might be occasioned; this view was strengthened by my frequently observing copper deposited upon some of the immersed portions of the platinum, and where this happened an excess of hydrogen was generally found to have been absorbed: to examine the accuracy of this view I caused

Experiment 2,—Four cells to be charged with a solution of sulphate of copper, and connected in closed circuit; after twenty-four hours' work, the liquid in the oxygen and hydrogen tubes had risen equally in three of the pairs, but in the fourth the liquid in the hydrogen tube had risen rather more than twice as high as in any of the others, and the whole of the platinum in this tube, from the water-mark downwards, was covered with metallic copper; it was thus evident that a slight precipitation having commenced on this platinum from some local circumstance which offered less resistance in this cell than in the others, a separate local current had been established, the hydrogen and the copper acting as a voltaic circuit, fresh copper had been constantly deoxidated at the expense of the hydrogen: the phenomenon is perfectly analogous to that observable in an ordinary sulphate of copper battery, when a slight portion of copper is deposited upon the zinc, and a local current is established by which the zinc is worn into a hole without contributing to the general current.

I have been thus particular in order to explain points in the action of this battery which might seem exceptions to the law of definite electrolysis, or what perhaps we should here call electro-synthesis; as a general result, the equivalent action of the battery was very beautiful; with fifty cells in action there was but a trifling difference in the rise of liquid in all the cells, and the rise of gas in the voltameter appeared so directly proportional, that an observer unacquainted with the rationale of a voltaic battery, would have said the gases from the exterior cells of the battery were conveyed through the solid wires and evolved in the voltameter; and had this been the first voltaic battery ever invented, this probably would have been the theory of its action.

In my original paper, I considered the points of voltaic action to be those where

the liquid, gas, and platinum met; and it was to increase the number of these points that I employed platinized or spongy platinum; indeed, from what I have since observed, I have much doubt whether I should have obtained any success had I used smooth platinum. The local action detailed in the last experiment, however, made me anxious to ascertain whether the principal points of action were those which I had originally believed, or whether the gases entered into solution first, and were then electro-synthetically combined by the immersed portion of the platinum; whether, for instance, the efficient parts of the plates were the parts $p\ q$, $p'\ q'$ (fig. 4), or $q\ r$, $q'\ r'$. To ascertain this the following experiment was made:—

Experiment 3.—A battery of five cells was constructed, in which the platinum reached only to half the height of the tubes (see fig. 10). This was charged with oxygen and hydrogen, so that the liquid just covered the extremities of the platinum. In this case we have only the immersed portions of the platinum, $q\ r$, $q'\ r'$, and can examine the action of the gases which enter into solution, and are unaffected by the platinum until in solution. This battery so charged gave a very trifling action indeed; it would not decompose iodide of potassium, and but slightly affected a highly sensitive galvanometer; but when a little gas was added, so as to expose the platinum to the gaseous atmosphere, a considerable current was developed, and a single pair decomposed the iodide.

If, again, a battery of this description (fig. 10) be charged so that the water-mark is below the upper edge of the platinum, and the ends are connected in closed circuit, the liquid rises in both tubes until that in the hydrogen tube has reached the top of the platinum, and then there is no further rise. This experiment decides the question as to what is to be considered the working portion of the battery, but it does not positively decide whether solution and electrolysis are contemporaneous or successive, as it may be said that even what I have termed the exposed parts of the platinum are covered with a film of liquid. I should myself hesitate for the present to express a decided opinion on this point; my first impression was, that there would be, as it were, three sets of points in contact, but I have not been able to devise an experiment definitively to settle this point*.

I aimed next at further establishing the analogies of this battery with the ordinary voltaic battery, *i. e.* regarding the hydrogen tube as analogous to the plate of zinc or other oxidable metal at the anode; I wished to see how far this relation was borne out. It was beautifully shown in

Experiment 4,—Where a single pair was charged with oxygen and hydrogen, and a second with hydrogen in one tube, the other being filled with dilute sulphuric acid; when the hydrogen of the second was metallically connected with the oxygen of the first, and the liquid of the second with the hydrogen of the first, as in fig. 11, bubbles of gas rose from the platinum, which proved, as I anticipated, to be hydrogen. In

* I have sometimes remarked when mixed oxygen and hydrogen have been collected in one tube of the gas battery over distilled water, the addition of a little sulphuric acid causes the gases rapidly to disappear.

short, though it required four pairs to decompose water with immersed platinum electrodes, yet the platinum in the atmosphere of hydrogen being analogous to an oxidable anode, one pair was with this assistance sufficient to decompose water, just as one pair of an ordinary battery will decompose water with an anode of copper.

The nitric acid battery, an account of which I originally published in 1839, having shown me the value of highly oxygenated acids and peroxides as voltaic excitants*, I determined, with a view of further extending the analogy of the gaseous and metallic voltaic batteries, to try the nitric acid as an electrolyte with the gas battery. Therefore,

Experiment 5,—I charged a battery with hydrogen and nitric acid in alternate cells, the nitric acid being only diluted sufficiently to prevent injury to the wooden parts of the battery. With this arrangement I found that three cells were capable of decomposing water, and thus, here also, the analogy held good, the gaseous hydrogen deoxidating the nitric acid in this arrangement, just as nascent hydrogen does in the metallic battery.

I now endeavoured to produce the converse effects, viz. to form a battery in which oxygen should be the gaseous element, and be absorbed by an electrolyte having an affinity for it. To this end,

Experiment 6,—I caused a battery of ten cells to be charged, the one set of tubes with oxygen and the alternate tubes with solution of protosulphate of iron. This battery decomposed iodide of potassium, but was not able to decompose water; the tubes which contained the solution of protosulphate represented the hydrogen tubes of the ordinary gas battery. The voltaic action caused by oxygen and protoxide of iron was, however, but temporary†. After a few hours it abated, the iodide was no longer decomposed, and the liquid did not rise perceptibly in the tubes containing oxygen; the solution when tested by ferrocyanide of potassium gave a blue precipitate, indicating the presence of peroxide, but the greater portion of this was probably formed at the expense of the atmospheric air.

In the last experiments and others, I had observed that a more decided effect was obtained when free hydrogen alone was present than when oxygen was alone. In my former paper I attributed this to the atmospheric air in solution, and for convenience of arrangement I have hypothetically assumed this explanation in the commencement of this paper, but the recent letter of Dr. Schœnbein induced me to look further into this point. Therefore,

Experiment 7,—I charged two batteries of two cells each, with hydrogen and dilute sulphuric acid in the alternate cells. When tested by iodide of potassium, each battery gave notable effects. One of these batteries was then placed, together with a cup containing phosphorus, in a shallow vessel of water; the phosphorus was ignited and a large glass vessel inverted over the whole; the terminal wires of the

* See Philosophical Magazine, May and October 1839, pp. 389 and 290.

† In experiment 26 it will be seen that a *continuous* current is obtained from oxygen and a liquid (ammonia); oxygen likewise gives a current with solution of cyanogen, and probably with many organic compounds.

battery, carefully protected by thick coatings of cement, passed under the edge of this vessel through the water, the exterior surface of which was covered with oil, more effectually to prevent the absorption of air. The terminal wires were then united and left so. After two hours, when the oxygen of the surrounding atmosphere had been exhausted by the phosphorus, the effect became more feeble, but continued throughout the evening. The next morning, however, the inclosed battery produced not the slightest effect upon the iodide, the liquid had risen in the hydrogen tubes about 0·2 cubic inch, but no other effect was perceptible. On the other hand, in the battery which had been placed by its side, charged in the same way, and similar in every respect but in the fact of being exposed to the atmospheric air, a very decided effect was produced; hydrogen had been evolved from one of the platinums to the extent of 0·3 cubic inch in the cell containing liquid, and a decided effect was produced on the iodide. The two batteries were left in this state for three more days; the decomposition and the evolution of hydrogen continued in the exposed battery, but none was perceptible in the inclosed one, although the liquid had risen a little more, viz. 0·1 cubic inch in the hydrogen tubes of the latter. After the four days above mentioned, the jar of nitrogen which covered the battery was taken away, and the action of the battery was tested by iodide of potassium. At first there was no action, but after about fifteen minutes, a slight action was perceptible; this gradually increased, and in two hours the action was equal to that of the battery which had been from the first exposed to the atmosphere. I cannot but regard this experiment as a conclusive negation of that view which regards hydrogen and water as the efficient agents in the gas battery. The opinion appears to me to have arisen from the circumstance of our working always in an atmosphere containing oxygen, and also from the fact of this latter gas being more soluble than hydrogen*. If we lived in an atmosphere of hydrogen, and if this gas were equally or more soluble than oxygen, I have little doubt that the converse effects would be observed. A battery charged with hydrogen in one set of tubes and acidulated water in the alternate ones, at first gives an effect nearly equal to an oxy-hydrogen gas battery, but the action rapidly declines in the former, while it is constant in the latter. Even the ordinary action of the gas battery when charged with oxygen and hydrogen appears to me unanswerable as to the point I am now discussing. When we see a battery of a number of cells at work, and the liquid gradually rising in the oxygen tubes, just in the proportion in which oxygen gas is eliminated in the voltameter, and when in a similar battery placed by its side, similarly charged, but not connected in closed circuit, not the slightest rise takes place in any tube, it seems impossible to adopt the conclusion that the oxygen has nothing to do with the current. Here we have no slight galvanoscopic effects, but chemical effects capable of quantitative admeasurement, capable of being continued to an extent only limited by the size of the apparatus, and equivalent to the chemical effects observable at the

* The tendency of oxygen to combine with platinum may also have its influence. See M. De La Rive's various experiments on this subject, Bibl. Univ. *passim*.

voltameter. If, on the other hand, hydrogen and water be the only active elements, what becomes of the hydrogen? If it combine with the water, we undoubtedly should by this means be able to obtain a suboxide of hydrogen*, a result of which I have not seen the slightest symptom in a long course of experiments on this subject. Even if we assume the action of the oxygen to be a depolarizing one, as suggested by Dr. Schœnbein, this comes to the same thing, as this depolarization can only be accounted for as being effected by the combination of the oxygen with hydrogen; and we might conversely assume this combination to be the efficient cause of the current, and the depolarization to take place in the hydrogen tubes. It seems to me that the effects at both anode and cathode are reciprocally dependent. The matter appears to me so clear that I should not have entered into detail upon it, were it not for the published letter of Dr. Schœnbein above mentioned, and that the superiority of the hydrogen is *primâ facie* very striking; knowing also the fondness with which we all adhere to preconceived opinions, as the consideration of the action of spongy or clean platinum on *mixed* gases led me to the discovery of the gas battery, I felt that I might be too apt to measure the correctness of my opinions by the success of the experiments to which they led, and therefore hesitated too confidently to rest upon what appeared to my mind positive demonstration.

Having verified the rationale of the action of the gas battery, I now sought to extend it to other gases, and caused arrangements of ten cells to be charged with such gases as were sufficiently insoluble to remain in the tubes time enough for experimental investigation. In all the following experiments, besides the ten cells charged in series, a single cell charged with similar gases and electrolyte was placed by the side, but with the terminals unconnected: thus, when the battery circuit had been closed for some time, by comparing the changes which had taken place in the battery tubes with those in the detached and unconnected pair, the effects due to solution, local currents, or other causes could be abstracted from those due to circulating voltaic action.

I shall arrange the following experiments in the order in which I instituted them, making such comments as may be necessary to explain my own deductions from the resulting phenomena. When not otherwise mentioned, the electrolyte will be considered as dilute sulphuric acid, sp. gr. 1·2.

Experiment 8.—A battery charged with oxygen and protoxide of nitrogen produced no effect upon iodide of potassium. Examined next day the liquid had not risen in the oxygen tubes; in the protoxide tubes it had risen to an average of 0·3 cubic inch, both in the battery and detached pair.

Experiment 9.—Oxygen and deutoxide of nitrogen produced a slight effect upon the iodide; the effect subsided after the circuit had been complete for a few minutes. On examining the battery after the circuit had been closed for twenty-four hours,

* I see by a recent paper of Dr. Schœnbein that he believes this to be the case, Archives de l'Électricité, No. 7, p. 73.

the liquid in the oxygen tubes had not risen; in the tubes containing deutoxide of nitrogen, the liquid had risen somewhat unequally in the different tubes to an amount averaging 0·2 cubic inch; in the detached pair it had risen to the same amount; not the slightest voltaic effect was now produced by the terminal wires.

Experiment 10.—Oxygen and olefiant gas decomposed the iodide, but rather feebly; after the circuit had been closed for twenty-four hours there was still a decomposition, which continued, but the action was extremely feeble. Two cells were allowed to remain arranged in closed circuit for fifteen days, a third being placed by the side, but with the terminals unconnected; at the expiration of this time the rise of liquid in the tubes was as follows:—

Rise of liquid in cells of closed circuit, in tubes of		Rise of liquid in cells of detached pair, in tubes of	
Oxygen	0·05 cubic inch.	Oxygen	0·02 cubic inch.
Olefiant gas . . .	0·4 cubic inch.	Olefiant gas . . .	0·3 cubic inch.

Rise of liquid apparently due to voltaic action,

In oxygen tubes . . .	0·03 cubic inch.
In olefiant gas tubes . .	0·1 cubic inch.

These quantities are too small to enable any satisfactory inference to be deduced as to the equivalents of these gases which contributed to electrolysis; the more so as the rise of liquid was not quite uniform, and the action due to solution was so much greater than that due to electrolysis.

I do not feel entitled to draw any other conclusion from this experiment than that there was a very feeble voltaic current produced by these gases; both the remaining oxygen and the olefiant gas were unaltered in character.

Experiment 11.—Oxygen and carbonic oxide produced notable effects upon the iodide, and slight symptoms of decomposing water; a few bubbles gathered upon the electrodes of an interposed voltameter; the effects continued; and at the expiration of fifteen days, the following was the state of the tubes in two cells, put aside as in the last experiment:—

Rise of liquid in cells of closed circuit,		Rise of liquid in tubes of detached pair,	
In oxygen tubes . .	0·12 cubic inch.	In oxygen tubes . .	0·02 cubic inch.
In carbonic oxide tubes	0·93 cubic inch.	In carbonic oxide tubes	0·7 cubic inch.

Rise of liquid apparently due to voltaic action,

In oxygen tubes	0·1 cubic inch.
In carbonic oxide tubes . . .	0·23 cubic inch.

Before the battery was charged for this experiment, the carbonic oxide had been carefully freed from carbonic acid by caustic potash. After action, the liquid gave a slight precipitate with lime-water, showing that carbonic acid had been produced by

the action. In this experiment the rise was more uniform in the different tubes than in the last, and the action more decided. The results, although on a small scale, appear more definite; thus we get the proportion as 1 : 2·3; and as the combining volumes of oxygen and carbonic oxide are as one to two, if we add the local action due to the oxygen of the air in solution, 1 to 2·3 is as near an approximation as can be expected. Though much superior to olefiant gas, the action of carbonic oxide is, however, very feeble when compared with that of hydrogen.

Experiment 13.—Oxygen and chlorine. Very considerable action on the iodide at first, but not constant; it abated within the first hour, and after twenty-four hours the action was extremely feeble, scarcely perceptible; the water had risen nearly to the top of the chlorine tubes, but the level in the oxygen tubes was unaltered. The chlorine was negative to oxygen, or in other words, the oxygen was in its voltaic bearing to chlorine as hydrogen to oxygen.

As in this experiment the water level in the oxygen tubes was unaltered, it appeared that this gas had little to do with the action, I therefore,

Experiment 14,—Charged the alternate tubes of a battery with chlorine and dilute sulphuric acid; the amount of action was much the same as in experiment 13, and equally transitory; a few gaseous bubbles were perceptible on the platinums in the oxygen cells, but not in sufficient quantity for examination. It is well known that chlorine of itself will slightly decompose water, forming hydrochloric acid, and evolving oxygen, and there is little doubt that the voltaic action here observed was due to this. There was no appearance of the platinum having been attacked in several experiments which I made with chlorine. So slight a chemical action will, however, give rise to voltaic effects, that the absence of any apparent corrosion is not conclusive. It is stated by chemists that gaseous chlorine will not attack platinum, but that it is only when nascent it combines with this metal; *non constat* however, that in the gas battery the chlorine at the initiatory instant of its electro-synthesis may not be in a state analogous, as to its chemical energies, to that converse state called nascent, and therefore we cannot venture to negative the possibility of the platinum being slightly attacked. This circumstance, added to its extreme solubility and power of decomposing water, makes chlorine rather an unsatisfactory element for the class of actions developed by the gas battery.

Solutions of bromine, chlorine and iodine, have been before experimented on (I believe by Dr. SCHŒNBEIN and M. BECQUEREL) as to their voltaic relations, but in examining the voltaic relations of bodies in a gaseous state, or to express myself with more caution, in a state passing from gaseous to liquid, I tried,

Experiment 15,—One set of tubes charged with gaseous chlorine, and the alternate tubes with solutions of bromine and iodine. The chlorine was negative to both, *i. e.* was to these as oxygen to hydrogen.

I now tried hydrogen with several gases, but as it was next to impossible (I found

it quite impossible), in experiments on a large scale, perfectly to exclude atmospheric air from the solution*, voltaic action was produced in every case; and as with one exception (chlorine) oxygen was the most powerful electro-negative gas, the action of the atmospheric air entirely masked any effect which might have been produced by the other gases†. I shall, therefore, not go through these experiments in detail, but mention one or two only which appear interesting, for the reasons which I shall state.

Experiment 16.—Chlorine and hydrogen gave very powerful effects, as was expected by Dr. SCHŒNBEIN‡; water was decomposed between platinum electrodes by two cells. This is the most powerful gas battery§, but not very satisfactory, for the reasons above stated, experiment 13.

Experiment 17.—Hydrogen and carbonic oxide were tried in order to ascertain their voltaic relations. Hydrogen was much more electro-positive than carbonic oxide, or rather formed, with the oxygen of the atmospheric air in solution, a combination which overpowered the opposite tendency of the carbonic oxide and air.

Experiment 18.—Chlorine and olefiant gas gave a very feeble effect upon iodide of potassium. After four hours the liquid in the olefiant gas tubes had not risen more in the closed circuit than in the detached pair; the chlorine was nearly all absorbed in solution.

Experiment 19.—Chlorine and carbonic oxide gave very notable effects; ten cells decomposed water. From the extreme solubility of the former gas, the equivalent relationship could not be ascertained.

It now occurred to me that as oxygen and hydrogen are evolved from water by electrolysis, and conversely form water by electro-synthesis, so some other gases which are evolved from certain electrolytes by voltaic action, might, when arranged as a gas battery with the electrolyte from which they are evolved, give rise to a current, although they would not do so when arranged in circuit with a different electrolyte. To test this view I tried,

Experiment 20,—Oxygen and deutoxide of nitrogen in alternate tubes of the gas battery, with dilute nitric acid; the effects were however precisely similar to experi-

* Gases will creep by a species of endosmose through water. Some time ago I kept inverted over water for two months, a vessel divided by a diaphragm of porous ware, on one side of which was oxygen gas, on the other hydrogen; the diaphragm was constantly wet from capillary attraction; at the end of that period the water had risen considerably, and the gases on each side detonated.

† See Postscript.

‡ See his letter, Philosophical Magazine, March 1843.

§ Chlorine, in its voltaic relations, may be considered as the converse of zinc, both decomposing water, but the one liberating oxygen, the other hydrogen; thus a tube of the gas battery charged with chlorine, and having acidulated water as an electrolyte, and zinc as a positive element, forms a combination of which one pair will decompose water. I have tried to render this combination practically useful, by charging the negative cell of a nitric acid battery with peroxide of manganese and muriatic acid, but the supply of chlorine thus obtained is insufficient for quantitative voltaic effects, though the intensity is great.

ment 8, viz. a very feeble action for a few minutes, then a cessation, and no continuous chemical action.

Experiment 21.—For the same reason oxygen and nitrogen, with solution of sulphate of ammonia, were tried; this arrangement produced at first a slight effect upon the iodide, which soon ceased, and after several days there was no more rise of liquid in any cell of the closed circuit than in the detached cell; the rise of liquid in both was very trifling indeed (about 0·01 cubic inch), and had evidently nothing to do with voltaic action. In this experiment, and in every experiment that I have tried, I have perceived a trifling action for the first few minutes. This I should have attributed to accidental causes, such as slight impurities in the gases, slight metallic deposits on the plates, &c., but that it is always in the direction which theory would indicate. Thus in the present experiment, the appearance of iodine indicated oxygen to have the same voltaic relation to nitrogen as it has to hydrogen. This temporary effect, therefore, appears to me analogous to that action called by continental experimentalists polarization, an apparent tendency to action, *i. e.* an arrangement of molecules preliminary to electrolysis, but incapable of producing a continued current. In this and many other experiments with the gas battery I have observed this effect, but have never been able to produce any chemical change or electro-synthetic absorption of nitrogen.

Experiment 22.—As oxalic acid when electrolysed evolves at the anode a mixture of oxygen and carbonic acid, and at the cathode hydrogen and carbonic oxide; for the reasons above stated, I charged a gas battery with carbonic acid and carbonic oxide in the alternate tubes, and with oxalic acid as an electrolyte; a slight effect was produced, the carbonic oxide being to the carbonic acid as hydrogen to oxygen; but the current was evidently due to the atmospheric air in solution combining with the carbonic oxide; this I proved by some of the test experiments before mentioned, which I need not recapitulate.

Experiment 23.—Hydrogen, nitrogen, and sulphate of ammonia. This combination also gave effects with which the nitrogen appeared to have nothing to do, this gas being perfectly unaffected; I tried other experiments on this point, but they all led to the same conclusion, viz. that my idea of realizing a voltaic action by conversion of the ordinary effects of electrolysis was erroneous. It may be that the above gaseous products of electrolysis are secondary, and that water is the only electrolyte in these cases; but for this, as for many other theoretical questions, there are so many arguments *pro* and *con*, that it is not worth while to dilate on them unless they can be shown to lead, or to be likely to lead, to some new valuable facts or natural relations.

Reviewing the above experiments, it appears that chlorine and oxygen, on the one hand, and hydrogen and carbonic oxide, on the other, are the only gases which were decidedly capable of electro-synthetically combining so as to produce a voltaic current*. I should perhaps except olefiant gas, which appears to give rise to a conti-

* See Postscript.

nuous though extremely feeble current; and the vapours of bromine and iodine, were they less soluble, would probably also be found efficient as electro-negative gases.

It now occurred to me that as several of these gases (take as an instance nitrogen) were absolutely without effect in the gas battery, this would form a valuable instrument for the analysis of atmospheric air or other mixed gases. I therefore procured,

Experiment 24,—Two narrow cubic inch tubes of seven inches long, carefully graduated into 100 parts. These were immersed in separate vessels of dilute sulphuric acid, and filled with atmospheric air exactly to the extreme graduation; the water-mark within the tube was examined when exactly at the same level as the exterior surface of the liquid; folds of paper were used to protect them from the warmth of the hands, and thus prevent expansion; the barometer and thermometer were examined, and every precaution taken for accurate admeasurement. One of these tubes was left empty in order to ascertain, and eliminate from the result, the effect of solubility. Into the other was placed a strip of platinized platinum foil, one quarter of an inch wide. This strip of foil was connected by a platinum wire with another strip placed in a tube of hydrogen and inserted in the same vessel. The apparatus is shown in fig. 12. After the circuit had been closed for two days, the liquid was found to have risen in the tube *a* twenty-two parts out of the 100; in the tube placed by its side, it had risen one division. The tubes were allowed to remain several days longer, but no further alteration took place. This analysis gives therefore twenty-one parts in 100 as the amount of oxygen in a given portion of air.

Experiment 25.—The tube *a* (fig. 12) was charged with nitrogen to a given mark, and 0·5 cubic inch of pure hydrogen added, the tube *h* was then charged with oxygen, and the circuit closed. Examined after twenty-four hours, the water had risen in the tube *a* exactly 0·5 cubic inch. The apparatus was left in this state for several days, but without any further effect; the voltaic action had thus perfectly exhausted the hydrogen and there stopped.

These experiments are sufficient to prove the accurate eudiometric action of the gas battery; performed on a large scale this method of eudiometry appears to me likely to possess some advantages. In the eudiometer of Volta, when gases containing oxygen are to be analysed, if the hydrogen added for detonation be impure, the result is of course erroneous. The same may be said of the detonation by spongy platinum, or by a wire heated by a voltaic current, which I formerly proposed*.

If, on the other hand, gases containing hydrogen are to be analysed, errors may result from any impurities in the oxygen which is added, or from inaccuracy in the measurement of either gas; in the electrolytic method of eudiometry, the quantity or purity of the hydrogen, in the one case, is of no importance, and in the other, the quantity or purity of the oxygen, that is, provided there be sufficient to exhaust the equivalent to be abstracted from the mixed gas subjected to eudiometry.

* Philosophical Magazine, Aug. 1841, p. 99.

It should be observed, that in these experiments only a single pair of the gas battery can be used, as, if more be employed, the electrolyte is likely to be decomposed, and gas added to the compound*. The process is rather slow, but I think very sure. Another valuable application of this process is, that it affords (in experiment 24) a simple method of obtaining nitrogen of unquestionable purity. I know of no method which effects this object so perfectly. All the oxygen of the air is abstracted, as well as that free oxygen which may be contained in the liquid; and by subsequently introducing a little lime-water into the tube *a*, the trifling quantity of carbonic acid may be removed, or the same thing may be at once effected by using caustic potash as the electrolyte in the apparatus fig. 12.

Probably many other applications of the gas battery may suggest themselves to other experimentalists, and obviously many more changes may be rung upon the gases employed, and curious and valuable results obtained; I have, however, in this paper given a sufficient number of experiments fairly to open the subject; each appears so suggestive of new ones that it is difficult to know where to stop.

The experiments on eudiometry, which I have last named, induced me to refer to Dr. Henry's paper on Gaseous Analysis†, and on reading it I was struck with a coincidence between the action of spongy platinum on mixed gases and the gas battery, a coincidence strongly confirmatory of the views which led me to its discovery. I will endeavour briefly to state these, and I state them, not as being absolutely correct, for differences of opinion may exist on this as on every other scientific matter, but as being those which existed in my mind prior to the experiments, and which are considerably, and to me unexpectedly, strengthened by the results embodied in the above-mentioned paper of Dr. Henry.

My original deduction may be stated and exemplified as follows:—When pure or amalgamated zinc is immersed in acidulated water, the oxygen, as is well known, will not combine with the zinc; but touch both zinc and liquid with platinum and combination ensues, the platinum being unaltered. So with a mixture of oxygen and hydrogen, the gases, although in intimate contact, will not chemically unite, but touch them with clean platinum and more or less rapid combination ensues. Here also the platinum is unaltered. Leaving out of the case any purely hypothetical explanation, why may not effects so similar in their character be related in other respects? In the voltaic combination the platinum is heated during action, and if the surfaces, and consequently the quantity of electro-chemical action be considerable, it is ignited; so in the catalytic combination, if the platinum be thin and of large extent, or in the form of a sponge, which still more increases its surface, it is ignited. Why, therefore, may we not regard the detonation of gas by platinum as a voltaic effect? or the combination of oxygen and zinc by the presence of platinum a catalytic effect? The only difference is, that gases do not admit of that interchangeable relation of particles which we call electrolysis. The necessity for this interchange is,

* See Postscript.

† Philosophical Transactions, 1824.

however, removed when the gases are in a state of such intimate admixture that it is not requisite to convey the action through a chain of particles; in the gas battery this chain is supplied by the intervening electrolyte, and thus the same action which is local in the experiments of Döbereiner is circulating in the gas battery; the latter bears the same relation to the former as the action of the ordinary voltaic battery does to the normal phenomena of chemical affinity. This relation is confirmed by the facts detailed in the paper of Dr. Henry, as the gases which he there found would combine by the presence of spongy platinum, are precisely those which will combine in the gas battery; thus oxygen and hydrogen combine rapidly, oxygen and carbonic oxide much more slowly, and oxygen and olefiant gas very feebly, so much so, as, in Henry's experiments, to require heat to induce combination. Of course chlorine and hydrogen, which will unite without platinum, will, *à fortiori*, unite with the aid of platinum, or they may in the gas battery occasion secondary action; the oxygen evolved by the decomposition of water by the chlorine combining with the free hydrogen in the tube. As oxygen and ammonia will, when at a slightly elevated temperature, combine by the influence of spongy platinum, forming water and leaving nitrogen, I now in order further to test this relation, tried

Experiment 26.—Ten cells of the gas battery were charged with oxygen and solution of ammonia, with a little sulphate of ammonia added to improve its conducting power. This arrangement produced a moderate effect upon the iodide, which was continuous; the liquid rose slowly but uniformly in the oxygen tubes; a gas was evolved in the alternate tubes, which proved to be pure nitrogen. After three weeks closed circuit, the gases collected, measured, and averaged gave for each tube,

Nitrogen evolved . . . . = 0·07 cubic inch.
Oxygen absorbed . . . . = 0·12 cubic inch.

Experiment 27.—To examine whether the alkaline character of ammonia had any thing to do with the effect, ten cells were charged with oxygen and solution of caustic potash, but produced no effect.

These experiments are strongly corroborative, and seem to me conclusive as to the relation between the action of the gas battery and catalysis by spongy platinum. Experiment 26 is also remarkable in regard to the binary theory of electrolysis, but upon this point I will not here enter.

Applying the hypothesis of Grotthus to the gas battery, we may suppose that when the circuit is completed, at each point of contact of oxygen, water and platinum, in the oxygen tube, a molecule of hydrogen leaves its associated molecule of oxygen to unite with one of the free gas; the oxygen thus thrown off unites with the hydrogen of the adjoining molecule of water; and so on until the last molecule of oxygen unites with a molecule of the free hydrogen; or we may conversely assume that the action commences in the hydrogen tube. In all these cases we should ever bear in mind that we proceed by steps which nature, as hitherto tested by experiment, has not recognised. All we can safely predicate of the actions at anode and

cathode is that they are correlations; although they take place at a distance, the one has no more been proved to take place without the other, or before the other, than height has been proved to exist without depth. I therefore allude to this hypothesis, not as literally adhering to it, but because it is generally received, and may tend to associate the action of the gas battery with the ordinary phenomena of electrolysis.

A number of hypotheses has been and may be proposed to account for these and other mysterious phenomenal relations; they all agree in being assimilations of what is unfamiliar to what is familiar. They are undoubtedly useful as didactic illustrations, and it is as such that they have hitherto contributed to advance science. It is, however, a curious circumstance, and worthy of some consideration, that the voltaic hypothesis of GROTTHUS, the emissive and undulatory hypotheses of light and heat, and, as far as I am aware, all physical hypotheses hitherto propounded, represent natural agencies as effects of *motion* and *matter*. These two seem the most distinct, if not the only conceptions of the mind, with regard to natural phenomena, and when we try to comprehend or explain affections of matter which are not obviously modes of motion, we hypothetically or theoretically reduce them to it: the senses *perceive* the different effects of sound, light, heat, electricity, &c., but the mind appears capable of distinctly *conceiving* them only as modes of motion. Does not this supply an argument that all physical agencies are reducible to these elements of mental conception? Or are we to look for new powers of mind, in other words, will greater familiarity with phenomena, at present recondite, enable the mind more clearly to comprehend them, and avoid the necessity of referring them theoretically to more familiar, and apparently more simple phenomena? To pursue this curious inquiry would involve me in a discussion foreign to the object of this paper and to the general character of contributions to the Royal Society, but the question arises so immediately out of the subject, and is so necessary to explain my own view, that I trust this brief statement of it will be considered sufficiently pertinent. It touches upon that interesting, scarce definable boundary, where physical merges into metaphysical science.

There are one or two other theoretical points as to which the gas battery offers ground of interesting speculation; the contact theory is one. If my notion of that theory be correct, I am at a loss to know how the action of this battery will be found consistent with it. If, indeed, the contact theory assume contact as the efficient cause of voltaic action, but admit that this can only be circulated by chemical action, I see little difference, save in the mere hypothetical expression, between the contact and chemical theories; any conclusion which would flow from the one would likewise be deducible from the other; there is no sequence of time in the phenomena, the contact or completion of the circuit and the electrolytical action are synchronous. If this be the view of contact theorists, the rival theories are mere disputes about terms. If, however, the contact theory connects with the term contact an idea of force which does or may produce a voltaic current independently of

chemical action, a force without consumption, I cannot but regard it as inconsistent with the whole tenor of voltaic facts and general experience.

Another point of theory suggested by the gas battery, is the relation of latent heat in the different cells of the battery and voltameter. According to our received theory of caloric, oxygen and hydrogen cannot assume the gaseous from the liquid state without rendering sensible heat latent. Now, as in the gas battery the gases evolved from the liquid in the voltameter must require and absorb precisely as much heat as is set free by the gases becoming liquid in each cell, it may be a curious subject of future inquiry (an inquiry which that beautiful instrument, the thermo-multiplier, will materially aid) to ascertain whether the heat absorbed in the voltameter be exacted from surrounding bodies, or whether it be supplied by the action of the battery itself, i. e. as the chemical force in the voltameter is conversely equivalent to that in each cell of the battery, and the calorific force at the voltameter is also the converse equivalent of that in each battery cell, whether there is the same mutual dependence of the latter as of the former forces. The action in the voltameter of ordinary batteries would argue strongly against the proposition, that the heat is exacted from surrounding bodies, as it is well known that water when electrolysed has its temperature rather increased than diminished; and I have found, when decomposing water with the nitric acid battery at a rate of 150 cubic inches a minute, a very considerable augmentation of temperature in the liquid subjected to decomposition, so much so, that if the quantity was not considerable, it was heated to ebullition. Much of this adventitious heat may have arisen from the restriction of the circuit by the voltameter plates and connecting wires, but if the gas battery be supposed to supply exactly sufficient heat, or (to use a license of expression) to convert electricity into sufficient heat to satisfy the demands of the expanding gases,—each battery cell being able by the condensation of its respective gases to afford this supply,—a rise of temperature ought to be perceptible in the whole battery equal to the heat produced by the condensation of gases in all the cells, minus that of one cell. I have not as yet been able to detect any elevation of temperature due to the action of the gas battery, not having in my possession any instrument capable of detecting such delicate thermoscopic effects. I am, therefore, the more anxious to offer the point for the consideration of those who may have such instruments at their command; and here for the present I leave the gas battery and its theory.

London Institution,
March 12*th*, 1843.

Postscript, July 7th.

The length of time which has elapsed between the communication and printing of this paper, as it has enabled me to procure the apparatus fig. 8, will I trust be deemed

a sufficient reason for my adding a Postscript containing a few experiments with this form of battery, some of which I cannot but consider important.

Experiment 28.—In order farther to test the opinion expressed, p. 105, six cells of this battery were charged with pure hydrogen and dilute acid in the alternate tubes. When first charged they decomposed water freely, but after the circuit had been closed for a short time, to exhaust the oxygen of the atmospheric air in solution, they produced no voltaic effect; the whole series of six would not decompose iodide of potassium; when, however, a little air was allowed to enter any one of the tubes containing liquid, that single cell instantly decomposed the iodide; three cells were put aside, each in closed circuit; at the expiration of a week these produced no effect upon a galvanometer, nor was there any gas evolved in the tubes containing liquid; the stoppers were now taken out, and the liquid in the hydrogen tubes rose to an average of 0·3 cubic inch; each cell contained a pint, and we may therefore regard 0·15 cubic inch as the amount of oxygen held in solution by this quantity of acidulated water. Were it not for the extreme practical difficulty of perfectly excluding atmospheric air for a long period, the above would furnish an excellent method of examining the quantity of oxygen held in solution by water, and by applying the proper calculus we might read off on our galvanometer scale the infinitesimal bubbles of gas contained in a given bulk of liquid; if, however, the acid water or the hydrogen contain foreign ingredients, a very different result follows, and the liquid, for reasons which will now be obvious, frequently rises considerably in the hydrogen tubes.

Experiment 29.—I repeated experiment 24 with the battery fig. 8, expecting that as the external air was shut out I should obtain the result more speedily; I was indeed not without a vague hope of producing some effect upon the nitrogen. The first result did follow; upon taking out the stoppers the morning after the battery had been charged, the liquid rose in the air-tube one-fifth of the gaseous volume. I now closed it again and examined it three days afterwards; a very curious effect had taken place; the volume of the gas in the air tube which had previously contracted had now *increased*, and it continued slowly increasing day after day. I at first believed that the nitrogen was decomposed, but after many conjectures and experiments found that the increase was due to the addition of hydrogen, a fact to me more extraordinary than the decomposition of nitrogen would have been. On repeating the experiment with nitrogen instead of air the same effect took place, but of course without the previous contraction. I now returned to battery fig. 4; several of these cells charged, some with atmospheric air and hydrogen, and others with nitrogen and hydrogen, did not exhibit the effect, though suffered to remain six weeks, each in closed circuit.

To ascertain whether the vacuum formed by the abstraction of oxygen from the liquid had anything to do with the above effect, a central narrow tube, open at both ends, was substituted for the stopper in the battery fig. 8; the hydrogen was still evolved. Not to detail a tedious set of test experiments, I at length found that two

points were essential to obtaining the effect with certainty; first, the exclusion of any notable quantity of atmospheric air from solution; and secondly, great purity in the hydrogen. In the former case, when the hydrogen could find oxygen to combine with, it was not evolved; in the latter, there would be mixed or rather diluted gas on both sides, and the forces would be balanced; thus I have never succeeded in obtaining the effect in the open battery, fig. 4, with hydrogen obtained in the ordinary way from granulated zinc or iron filings, but have sometimes succeeded with hydrogen procured by electrolysis. In the battery fig. 8, I have succeeded in producing the effect, but in a feeble degree, from hydrogen obtained in the common way, but have never failed with hydrogen obtained by electrolysis. Oxygen of the greatest purity, voltaically associated with nitrogen, does not produce a similar effect. The above unexpected results render it necessary, in order to ensure accuracy in the eudiometric experiment 24, either purposely to use common hydrogen in the batteries figs. 4 and 12, or what is more expeditious and accurate, to use a battery similar to fig. 8, but with tubes longer in proportion to their width; and having first charged the tubes with hydrogen and atmospheric air, to allow these to remain in closed circuit until all the oxygen is abstracted and a little hydrogen added, by the electrolytic effect, to the residual nitrogen; then to substitute oxygen for the original hydrogen, which will in its turn abstract the hydrogen from the nitrogen and leave only pure nitrogen. I have frequently done this with perfect success.

Experiment 30.—Hydrogen and carbonic acid in battery fig. 8 produced the same effect. The volume of the carbonic acid was increased, and hydrogen was found to have been added to it. The effect therefore is not due to any peculiarity of nitrogen, but yet some gas is necessary, for experiment 28 proves that hydrogen alone will not decompose water. I need scarcely say, that when the above-mentioned effect took place an interposed galvanometer was deflected, but the current was much too feeble to decompose iodide of potassium.

I have tried, associated with hydrogen in battery fig. 8, carbonic oxide, olefiant gas, protoxide of nitrogen, and deutoxide of nitrogen; the two former produced no current or chemical effect, the two latter gave a current and were decomposed. The volume of the deutoxide contracted one-half, this was found to be nitrogen, which thenceforth was gradually increased by hydrogen. The volume of the protoxide did not undergo the previous contraction, except slightly from solubility, but its change of state was denoted by the absorption of hydrogen in the associated tube.

I likewise tried the effect of a vacuum and hydrogen, by charging a battery (fig. 8) with 1 cubic inch oxygen and 3 cubic inches hydrogen; the current was much enfeebled by the resistance offered by the vacuum, at first iodide of potassium was decomposed and the galvanometer needle whirled round. After twenty-four hours the galvanometer needle was only deflected 10°, thus a physical was opposed to, and resisted, a chemical force; the current however continued, and all the gas in the oxygen tube disappeared, except a minute bubble; this was probably nitrogen from the atmo-

spheric air in solution, which had escaped to fill the vacuum. When the stopper was taken out the liquid rose suddenly in the hydrogen tube 2·2 cubic inches, giving the equivalent of the oxygen in the tube and in solution. It is very possible that this experiment repeated might sometimes exhibit an evolution of hydrogen in the oxygen tube arising from the escape of the nitrogen of the atmospheric air in solution, and acting as in experiment 29, but I have not seen this effect take place. It should be distinctly understood, that in all the experiments mentioned in this Postscript, except the first part of experiment 28, *single* cells only were used.

Upon the theory of the experiments 29 and 30 I will venture no positive opinion. That gaseous hydrogen should *abstract oxygen from hydrogen*, without the latter forming any other combination, is a fact so novel, that any attempted explanation is likely to prove premature. If, contrary to the views of DALTON, we suppose that gases when mixed are held together by a feeble chemical affinity, then we may say that the affinity of the nitrogen or carbonic acid for hydrogen produces the effect; the affinity of the oxygen of the water, being balanced between the hydrogen in the liquid and that in the tube, would enable the resultant feeble affinity of the nitrogen for hydrogen to prevail; but on this supposition, why does not oxygen produce an analogous effect? Its tendency directly to combine with platinum may indeed be regarded as an opposing force, but this tendency is by many considered hypothetical. On the other hand, it may be called an effect of contact; but this, unconnected with a chemical theory, presents no other idea to the mind than the fact itself presents, it furnishes no link by which we may extend the phenomena. I therefore, until a better theory be found, should be inclined to adopt the former view, and to regard mixed gas as in a state of feeble chemical union, the more especially as throughout nature we find no absolute lines of demarcation, though for conventional reasons we are obliged to adopt them; there must be many cases in which it is difficult, if not impossible, to draw the line between mechanical mixture and chemical combination.

In conclusion, I would say with regard to the whole of the experiments contained in this paper, that a longer time and more experience may give positive results in cases where I have only obtained negative ones; it is far from impossible that since curious solid combinations are formed by slow electrical currents, as in the experiments of CROSSE and BECQUEREL, so novel gaseous or liquid products may be obtained by the long-continued voltaic action of gases and liquids. This time alone can show.

For previous experiments and theories on the combination of gases by platinum, I may refer to DÖBEREINER's paper, Phil. Mag. Oct. 1823, in which I find he expresses an opinion that it is a voltaic effect; to the papers of DULONG and THENARD, Annales de Chimie, tom. 23 and 24, and to FARADAY's Experimental Researches, Series 6. The various experiments on polarized electrodes of RITTER, FARADAY, DE LA RIVE, BECQUEREL, MATTEUCCI, and SCHŒNBEIN, are also in point.

IX. *Contributions to Terrestrial Magnetism.—No. IV.*

By Lieut.-Colonel EDWARD SABINE, *R.A., F.R.S.*

Received May 5,—Read May 18, 1843.

§ 7. *Second Series of Magnetic Determinations, by Captain Sir* EDWARD BELCHER, *R.N.*

IN the present number of these Contributions, I resume the consideration of Captain Sir EDWARD BELCHER's magnetic observations, of which the first portion, viz. that of the stations on the north-west coast of America and adjacent islands, was discussed in No. II. The return to England of Her Majesty's ship Sulphur by the route of the Pacific Ocean, and her detention for some months in the China Seas, have enabled Sir EDWARD BELCHER to add magnetic determinations at thirty-two stations to those at the twenty-nine stations previously recorded.

In the notice of the earlier observations, a provisional coefficient was employed in the formula for the temperature corrections of the results with the intensity needles, as no experiments had then been made for the determination of their individual coefficients. As soon therefore as Sir EDWARD BELCHER had completed the observation of the times of vibration of those needles at Woolwich, as the concluding station of the series made with them, Lieut. RIDDELL, R.A. undertook the determination of their several coefficients, which was performed in the manner and with the results described in the subjoined memorandum.

"The observations were made in the instrument room attached to Lieut.-Colonel SABINE's office in the Royal Military Repository, Woolwich.

"The instruments rested on wooden stands detached from the floor.

"The deflections were observed with one of WEBER's transportable magnetometers; the variations of declination and horizontal force with the larger instruments.

"The needles were placed upon open Y supports, in the centre of a wooden trough about nine inches in length, six broad and six deep, and were fixed so that their magnetic axes should be in the line passing through the centre of the suspended magnet perpendicular to the magnetic meridian.

"The trough was filled alternately with warm and cold water, and the instruments were registered after a sufficient time had elapsed to allow the needles to take up the temperature of the water; care was taken not to raise the temperature of the water above 110° or 120°, to avoid the permanent loss of magnetism which might have been occasioned thereby.

"October 13th. Needle 5.

Times.	Temp.	Diffs.	Spare Magnetometer. 1 Sc. Div. = 1′·00.	Declination Magnetometer. 1. Sc. Div. = 0′·698.			Bifilar Magnetometer. $k = \cdot00016 : q = \cdot00016$ approx.			
				Readings.	Corrected Readings.	Diffs.	Readings.	Temp.	Corrected Readings.	Diffs.
h m	°	°	Sc. Div.	Sc. Div.	Sc. Div.	Sc. Div.	Sc. Div.	°	Sc. Div.	Sc. Div.
21 40	......	......	250·5	42·7	42·7					
22 3	54·0	......	249·8	228·8	229·3	186·6	180·9	54·3	180·9	
56	92·0	38·0	248·3	225·3	226·8	2·5	179·5	55·0	180·2	+0·7
23 26	56·2	35·8	246·1	226·7	229·8	3·0	179·0	55·3	180·0	−0·2
47	86·0	29·8	245·0	223·5	227·3	2·5	179·2	55·7	180·6	−0·6
24 00	56·5	29·5	243·0	224·3	229·5	2·2	179·7	56·0	181·4	+0·8
		4)133·1				10·2				+0·7
		33·3				2·55				+0·2

$$q = \frac{2{\cdot}55}{33{\cdot}3 \times 186{\cdot}6} + \frac{0{\cdot}2 \times \cdot00016}{33{\cdot}3} = 0{\cdot}000411.$$

October 22nd. Needle 5.

Times.	Temp.	Diffs.	Spare Magnetometer.	Readings.	Corrected Readings.	Diffs.	Readings.	Temp.	Corrected Readings.	Diffs.
22 21	......	......	238·8	1703·6	1703·6					
34	66·4	......	238·0	1586·2	1586·8	116·8	190·6	45·3	190·6	
56	90·7	44·3	237·3	87·9	89·0	2·2	190·5	46·0	191·2	−0·6
0 18	58·0	32·7	235·3	85·3	87·7	1·3	191·2	47·0	192·9	+1·7
38	75·1	17·1	234·8	85·6	88·4	0·7	192·1	47·7	194·5	−1·6
57	54·9	20·2	234·6	84·0	86·9	1·5	193·7	48·5	196·9	+2·4
		4)114·3				5·7				+1·9
		28·6				1·425				+0·5

$$q = \frac{1{\cdot}425}{28{\cdot}6 \times 116{\cdot}8} + \frac{0{\cdot}5 \times \cdot00016}{28{\cdot}6} = 0{\cdot}0004266 + 0{\cdot}000003 = 0{\cdot}00043.$$

"The 'readings' are the means, each, of three or four separate readings, at intervals of two or three minutes.

"Similar series were observed with eight other needles; the approximate results for each needle are as follows:—

Date.	No. of Needle.	Value of q.	Means.
October 14.	5	0·00041	0·00042
22.	5	0·00043	
14.	6	0·00056	0·00065
November 22.	6	0·00074	
22.	7	0·000090	0·00005
24.	7	0·000017	
26.	8	0·00014	0·00014
26.	9	0·00012	0·00012
26.	10	0·00009	0·00009
28.	11	0·00019	0·00019
28.	12	0·00014	0·00014
29.	13	0·00022	0·00022

These coefficients have accordingly been used in calculating the results in the present Number. A careful examination of the observations at the foreign stations had led me to infer that Nos. 5. and 6. would probably be found to have larger coefficients than the other needles, which has proved to be the case. The variation in the amount of the coefficients in the different needles, considerable as it is, is not unprecedented; it probably depends on the quality and temper of the steel, and may be particularly influenced by the portions of soft iron which a needle may contain. A species of steel has been recently employed for magnets in the Russian observatories, in which the coefficient for temperature has even a negative sign, *i. e.* the magnetic intensity of the bar *increases* with heat. In a letter which I have received from M. ADOLPHE ERMAN, he describes this particular kind of steel as consisting of alternate very thin layers of soft iron and of steel, so that when heated the soft iron layers would increase their magnetic intensity, and the steel layers diminish theirs; the amount and sign of the coefficient depending on the preponderance of the layers of soft iron or of steel, which is subject to much variation. It is called "Boulat," or "damascened steel," and is considered the pride of the Uralian forges. In a bar of this steel, kindly sent me by General TCHEFFKINE, at the request of M. KUPFFER, the usual effect is thus reversed. Experiments made with it at Woolwich by Lieutenant RIDDELL gave the results stated in the following memorandum:—

"The effect of temperature on the bar of Russian steel, sent by M. KUPFFER, was tried in the usual manner by means of the magnet of the declination magnetometer, the bar being placed with its axis in the line passing through the centre of the suspended magnet perpendicular to the magnetic meridian. The subjoined observations furnish satisfactory proof that the ordinary effect of temperature on bars of steel which are hardened throughout is reversed in this bar, but the value of the coefficient, or change of force for 1° of FAHR. deduced from them, must be taken only as a rough approximation, as in addition to the probable error of the observations themselves, the bar was placed with its centre at a distance of three feet, or only $1\frac{1}{2}$ times its length from the magnetometer, in order to produce a sufficient deflection, the magnetism being weak *."

* After the completion of this experiment with the bar in the state in which it was received from General TCHEFFKINE, a portion was cut off, softened, and made into 3-inch cylinders of the dimensions used with the portable magnetic apparatus. The effect of temperature on one of these cylinders, hardened afresh and remagnetised, was tried in a similar manner, and the value of its coefficient found to be about ·0003, the force decreasing with an increase of temperature, which is the ordinary effect.

Abstract.

November 21st, 1842.

Times.	Temperature.			Spare Declination Magnetometer. $a = 2'{\cdot}30$.			Declination Magnetometer. $a = 1'{\cdot}00$.				Bifilar Magnetometer. $k = 0{\cdot}00015$.					Bifilar Thermometer.	
	Observed.	Means.	Diffs.	Readings.	Diffs.	Corrections.	Readings.	Corrected Readings.	Means.	Diffs.	Readings.	Corrected Readings.	Means.	Diffs.	$\frac{\Delta X}{X}$.	Temp.	Diffs.
d h m 20 23 40	°	Before deflection.		Sc. Div.	Sc. Div. Bar away.	′	Sc. Div. 30·0	Sc. Div.	Sc. Div. 30·0	Sc. Div.	Sc. Div.	Sc. Div.	Sc. Div.	Sc. Div.			
21 0 32	50·3	......	......	2·4	......	....	1484·1	1484·1	......	......	194·5	194·5	......	......	......	51·3	
0 50	100·0	54·3	45·7	3·0	0·6	1·4	1492·9	1491·5	1484·7	6·8	195·1	194·9	193·5	1·4	·00021	51·5	0·2
1 10	58·3	105·3	47·0	3·4	1·0	2·3	1487·6	1485·3	1492·5	7·2	193·0	192·5	193·0	0·5	·00007	51·8	0·5
28	110·5	57·0	53·5	3·6	1·2	2·8	1496·2	1493·4	1483·9	9·5	192·3	191·2	192·3	1·1	·00016	52·4	1·1
45	55·7	......	......	3·0	0·6	1·4	1483·9	1482·5	......		193·5	192·1	......	......	......	52·7	1·4
			48·7							7·8							

Approximately $q = \dfrac{7{\cdot}8}{48{\cdot}7 \times 1492{\cdot}5} = 0{\cdot}00011$.

"The 'readings' in the several columns so entitled are the means each of three or more observations at intervals of $1\frac{1}{2}$ or 2 minutes. The 'corrections' are obtained by multiplying the differences of the readings of the spare declination magnetometer by the ratio of the angular value of the two declination scales. The corrections for changes of horizontal intensity are omitted as inappreciable.

"The bar was placed in a wooden trough filled alternately with warm and cold water, and its temperature was registered by a thermometer near its centre."

We have next to consider the more important question of the steadiness with which the needles may have maintained their magnetic condition during a voyage of so many months, and under such numerous and various trials. When there are many needles, all of generally steady magnetism, their intercomparison affords on the whole a not unsatisfactory mode of discovering the periods when any one amongst the number may have sustained an accidental loss, and of obtaining an approximate correction for it. I have already shown in No. II. of these Contributions*, the steadiness of Nos. 5. 7. 8. 9. 11. 12. and 13. of Sir Edward Belcher's needles, from October 1838 to March 1839, by means of the observations made at Panama at both those dates. I have also noticed in the same paper that the intercomparison between March and November 1839, had shown that No. 8. was apparently more subject than the other needles to small occasional losses, and that I deemed it therefore less fit than the others for carrying on a chain of magnetic determinations. Subsequent experience with this needle has confirmed this early indication, as will be more fully shown in the sequel.

For the present investigation we shall therefore employ only Nos. 5. 7. 9. 11. 12. and 13.

A similar opportunity to the one above noticed (at Panama), of evidencing the *general* steadiness of these needles, was afforded by Sir Edward Belcher's return to Singapore in December 1841, having previously visited that station in the October of the preceding year: the agreement in the respective times of vibration at those two periods is shown in the following Table:—

Periods.	Designation of the Needles.					
	5.	7.	9.	11.	12.	13.
	s	s	s	s	s	s
October 1840	466·9	532·8	433·2	469·1	397·0	390·5
December 1841	465·8	532·3	434·0	467·8	397·9	390·4

We are therefore warranted by the observations at Panama and Singapore, in regarding the usual condition of these needles to be that of steady magnetism, subject nevertheless, as all magnets appear to be, to occasional loss of force from accidental causes, the nature and operation of which are not perfectly understood.

The ratio of the squares of the times of vibration of two needles, or the difference of the logarithms of the squares, at stations at which they were both used, should be a constant quantity (within the limit of errors of observation), if both needles have continued steady; consequently a loss of magnetism occurring in either will be shown by an alteration in the ratio exceeding in amount the ordinary errors of observation; if the ratio diminishes, the loss has taken place in the needle, which for the purpose of comparison is regarded as unity; if it augments, the loss is in the needle with which it is compared. A simultaneous loss in both needles to an equal amount will not

* Philosophical Transactions, 1841, Part I., p. 13.

indeed be detected; but when the intercomparison is extended from two to several needles, the improbability of all being affected at the same time and to an equal amount becomes considerable. It is still however possible, because the intercomparison can show nothing beyond the *relative* condition of the needles.

In the present case the incompleteness in this respect of the evidence furnished by the intercomparison, is supplied by Nos. 7. and 9. having been vibrated at Woolwich in August 1839 and in October 1842: the change in their times of vibration at those dates, compared with the loss of magnetism deduced for each by the intercomparison with the other needles, shows whether any and what *unaccounted* loss has taken place in the interval in those two needles, and consequently in all those compared with them.

In what has been said above, it has been assumed that a change taking place is always occasioned by a *loss* of magnetism in one or other of the needles; it generally is so; but should the case occur, that one of the needles should gain instead of lose by any accidental disturbance of its magnetism, the intercomparison with others would equally point it out and mark its character.

An alteration in the ratio of the squares of the times of vibration may be occasioned at a particular station by an observation error of unusual magnitude, or by some unknown accidental cause of a temporary nature affecting *at the one station only* the time of vibration of the needle which is compared; an alteration to nearly the same amount will, in such case, equally pervade its comparisons with all the needles; but this case is readily distinguished from that of a permanent loss or gain of magnetism, requiring a correction to be sought out and applied,—by the ratio reverting to its original amount at the succeeding stations.

The process which has been followed in assigning the corrections for the losses thus discovered to have taken place may be best shown by an example. On the simple inspection of the observations, it was evident that Nos. 5. and 7. had each sustained a loss of magnetism between the Seychelles Islands and Mojambo Bay in the Island of Madagascar. The logarithms of the squares of the times of vibration of No. 5. at the three stations preceding the period of the loss, and at the three stations following the same, being severally subtracted from the corresponding logarithms of the squares of the times of vibration of Nos. 9. 11. 12. and 13. at the same stations, the differences are arranged in the subjoined Table. The differences for each needle are seen to be nearly a constant quantity (a) at Penang, Point de Galle, and Seychelles; to have undergone a change between Seychelles and Madagascar; and to have become again a nearly constant, though a different, quantity (b) at Madagascar, the Cape of Good Hope, and Ascension. The amount of the change between Seychelles and Madagascar ($b - a$) is shown by No. 9. to be 9·9856; by No. 11, 9·9859; by No. 12, 9·9856; and by No. 13, 9·9859. The mean, 9·9857, must be added to the logarithm of the square of the time of vibration of No. 5. at Madagascar and all the succeeding stations, to make them strictly comparable with the observations of that needle at

the Seychelles and all preceding stations: or if the ratio of the intensity is sought between those stations and one visited subsequently to Madagascar,—(as for example Woolwich, where the observations with No. 5. were made in December 1842),—9·9857 must be subtracted from, or its arith. comp. 0·0143 added to, the squares of the times of vibration at the earlier stations.

Differences of the logarithms of the squares of the time of vibration of No. 5. with those of Nos. 9. 11. 12. and 13.

Stations.		No. 9.	No. 11.	No. 12.	No. 13.
Preceding the loss;	Penang	9·9401	0·0049	9·8674	9·8470
	Point de Galle	9·9406	0·0036	9·8678	9·8458
	Seychelles	9·9408	0·0041	9·8680	9·8481
	Mean (a)	9·9405	0·0042	9·8677	9·8476
Following the loss;	Madagascar	9·9265	9·9901	9·8530	9·8331
	Cape of Good Hope.	9·9261	9·9885	9·8530	9·8315
	Ascension	9·9256	9·9918	9·8538	9·8341
	Mean (b)	9·9261	9·9901	9·8533	9·8329
	$(b)-(a)=$	9·9856	9·9859	9·9856	9·9859

By a similar comparison, of which the particulars are also subjoined, No. 7. is shown to require a correction of 9·9885 to be added to the logarithms of the squares of the times of vibration at Madagascar and the subsequent stations, or of 0·0115 to be added to the logarithms at the stations antecedent to Madagascar, to render the series of observations with this needle before and after the loss thus ascertained comparable with each other.

Differences of the logarithms of the squares of the times of vibration of No. 7. with those of Nos. 9. 11. 12. and 13.

Stations.		No. 9.	No. 11.	No. 12.	No. 13.
Preceding the loss;	Penang	9·8232	9·8880	9·7505	9·7301
	Point de Galle	9·8217	9·8847	9·7489	9·7269
	Seychelles	9·8224	9·8857	9·7496	9·7297
	Mean (a)	9·8224	9·8861	9·7497	9·7289
Following the loss;	Madagascar........	9·8100	9·8736	9·7373	9·7166
	Cape of Good Hope.	9·8120	9·8744	9·7389	9·7174
	Ascension	9·8103	9·8765	9·7377	9·7188
	Mean (b)	9·8108	9·8748	9·7380	9·7176
	$(b)-(a)=$	9·9884	9·9887	9·9883	9·9887

The loss of magnetism thus manifested in Nos. 5. and 7. at the Seychelles is the most considerable change undergone by any of the needles between March 1839 and December 1842. The only change of nearly equal amount (being also a loss for

which the correction is 0·0093) was sustained by No. 7. at Mazatlan in November 1839, and has been noticed and the circumstances connected with it stated in No. II. of these Contributions*. The corrections of Nos. 5. 7. 9. 11. 12. and 13, derived from the intercomparison, commencing with the observations at Panama in March 1839, and ending with those at Woolwich in December 1842, are as follows: they are all additive at the stations named and at all antecedent stations, and render the whole series with each needle comparable throughout with each other, and with the observations at Woolwich in December 1842.

No. 5. 0·0143 from Seychelles; 0·0027 (additional) from San Blas.

No. 7. 0·0115 from Seychelles; 0·0013 (additional) from Amboyna; and 0·0093 (additional) from Mazatlan.

No. 9. 0·0018 from Point de Galle; 0·0021 (additional) from Singapore, October 1840; 0·0038 (additional) from Tahiti.

No. 11. 0·0035 from Jobie Island.

No. 12. 0·0020 from the Cape of Good Hope; 0·0012 (additional) from Point de Galle; 0·0030 (additional) from Macao, September 1841.

No. 13. 0·0034 from Amboyna; 0·0017 (additional) from Tahiti.

We have next to examine how far the corrections thus derived correspond with the change in the times of vibration of Nos. 7. and 9, shown by direct observation at Woolwich at the two dates of August 1839 and December 1842.

	No. 7.	No. 9.
	s	s
In August 1839 the times of vibration observed were	767·0	627·6
The corrections assigned by intercomparison are equivalent to .	+ 19·8	+ 5·6
Observed times of vibration in August 1839, corrected . . .	786·8	633·2
Observed times of vibration in December 1842	789·1	635·7
Differences	2·3	2·5

The differences are in the same sense in both needles, and are such as would correspond to a small loss of magnetism still undetected by the intercomparison. It is possible that they may be partially or wholly due to this cause, without prejudice to the effectiveness of the method itself, because, in its present application, the intercomparison has not been pursued to the correction of *very* small differences; it has however been carried out to such extent, that even the very moderate differences indicated by the above figures would not have escaped detection had they occurred at any single station or period. They correspond respectively to ·006 and ·007 parts of the whole horizontal force; and were there no liability to observation errors,—and were the horizontal force at Woolwich at all times a constant quantity,—we might be justified in meeting them with a special correction. But they are exceeded in amount by the fluctuations of the force itself, which is subject both to periodical variations, dependent on the hour and season, and to other fluctuations of irregular occurrence,

* Philosophical Transactions, 1841, p. 15.

which sometimes for several days together raise the intensity above, or depress it below, its average value; and experience shows that either from these natural causes, or from observation errors, or from both combined, the results obtained at the same station on different days with needles of assured steadiness, do occasionally vary to as great and greater amounts than those under consideration; we should scarcely be justified, therefore, in applying any further correction.

Employing the corrections obtained by the intercomparison of the needles, and combining the times of vibration of each at Panama in March 1839 with those at Woolwich in December 1842, we obtain the ratio of the horizontal force at Panama to the force at Woolwich, regarded as unity, by the several needles as follows:—

No. 5.	2·078	Mean 2·081.
7.	2·078	
9.	2·087	
11.	2·082	
12.	2·077	
13.	2·084	

The partial results do not differ from each other more than those might be expected to do which should have been obtained by the repetition of observations with one and the same needle.

The general table of results in the sequel has been calculated by the aid of the corrections thus derived, and the intensity as given by each of the needles severally is entered in the Table.

The time of vibration of No. 11. at Woolwich, in October 1842, appears to have been affected by some accidental cause of error. Its discordance with the general series was perceived a few days after the observations were made, and error suspected, because the time of vibration would have corresponded to a considerable *increase* in the magnetism of the needle. The suspicion was confirmed by the repetition of the observations at Woolwich on the 27th and 28th December 1842, and at Falmouth on the 9th of February 1843, though no cause has been discovered either then or subsequently for the error in the first observation. Viewing the more than usual importance of accuracy in the observations at a base station, I have selected a different station for that purpose for this particular needle, and have chosen Singapore, both because the ratio of the horizontal force at that station to the force at Woolwich appears to have been extremely well determined by Sir Edward Belcher's observations in 1840 and 1841, and because any error in that determination will be corrected with certainty before long by the absolute determinations at the magnetic observatory there. The horizontal force at Woolwich being unity, its value at Singapore is 2·135 by Sir Edward Belcher's observations in 1840, and 2·140 by those in 1841. The mean is 2·1375. The time of vibration of No. 11. at Singapore was $468^{s}·7$ in 1840, and $467^{s}·3$ in 1841; mean $468^{s}·0$ at 75° Fahr.

We have now to notice the two needles Nos. 6. and 8, which have not been included in the intercomparison which the others have undergone.

By means of the horizontal intensity derived for each station from the mean of Nos. 5. 7. 9. 11. 12. and 13, and the observed times of vibration of No. 8. at the several stations, the corresponding times of vibration which that needle would have had at the respective periods at Woolwich have been computed, and are as follows:—

	s		s
Mazatlan, November 1839	677·7	Singapore, October 1840	681·6
San Blas, December 1839	678·5	Singapore, December 1841	682·9
Martin's Island, January 1840	678·8	Penang, December 1841	683·2
Bow Island, March 1840	679·6	Point de Galle, January 1842	683·0
Tahiti, May 1840	678·8	Seychelles, February 1842	683·0
Nukulau, June 1840	679·6	Madagascar, March 1842	684·6
New Ireland, July 1840	680·7	Cape of Good Hope, April 1842	684·3
Jobie Island, August 1840	680·2	Ascension, May 1842	685·1
Amboyna, September 1840	680·7	Woolwich, October, December	686·1
Macassar, September 1840	681·8		

The progressive increase in the times of vibration indicates that No. 8. was continually parting with small portions of its magnetism, a condition, which, when it occurs in one needle amongst many, renders that particular needle of less value in general deductions than those which have the character of general steadiness with only *occasional* loss. Corrections might be assigned for No. 8, derived either from its comparison with the other needles, or on a supposition of uniform loss in reference to time or to occasions of employment, but the latter could only be regarded as approximate, and the former would add no independent value to the general conclusions. The observations with No. 8. therefore are given in the Tables, but no deductions have been made from them.

The derangement in the magnetic state of No. 6, which took place in a journey to the summit of the volcano of Conchagua in December 1838, and its subsequent unsteadiness, have been already noticed in No. II. of these Contributions. The magnetism of this needle continued unsettled for the whole remainder of the voyage, affording an instructive example of the extent of injury which an exposure to unfavourable circumstances may produce in a long-tried and valuable needle; the one in question having been in use during the twenty-one previous months without undergoing apparently the slightest change in its magnetism. It unfortunately happened that No. 6. is one of two needles, No. 5. being the other, which Sir EDWARD BELCHER employed throughout his voyage at stations where time did not permit him to use more than two; and it is desirable therefore to draw from the observations with No. 6. at such stations, all the evidence they are capable of affording. For this purpose I have made the stations at which several needles were used base stations, for the deduction of the force with No. 6. at any intermediate place where Nos. 5. and

6. only were employed: the deductions by No. 6. being in all such cases dependent on the determinations by all the other needles at the base stations visited immediately before and after. When the force at the intermediate place has appeared by No. 6. to be nearly the same, whether derived from the base station preceding, or the one following it, the mean result has been considered to have an independent value, and has been employed accordingly. When otherwise, the observations have been entered in the table, but no deductions have been made from them.

The values of the horizontal force which are contained in the final column of the general table are expressed in absolute measure, referring to the units prescribed in the magnetic Instructions which have received the sanction of the Royal Society*. Experiments made by Lieutenants LEFROY and RIDDELL in the Royal Military Repository at Woolwich in May 1842, with magnets of four inches in length, gave 3·72 as the approximate value of the horizontal force at Woolwich at that period, agreeably to the following memorandum:—

"The number 3·72, given as the approximate value of the horizontal intensity at Woolwich, expressed in English units of feet, seconds, and grains, was determined from experiments of deflection and vibration made with one of WEBER's transportable magnetometers.

"The experiments of deflection were made after the method of M. GAUSS, with the axis of the deflecting magnet perpendicular to the magnetic meridian, the angles being measured on the scale fixed over the reading telescope. The deflecting and suspended magnets were of the same dimensions, about four inches in length and four-tenths in diameter.

"The values of $\frac{m}{X}$ were calculated from the several pairs of observations by the formula

$$\frac{m}{X} = \frac{r'^5 \tan u' - r^5 \tan u}{2\,(r'^2 - r^2)}.$$

"The partial results, distances, and angles of deflection are given in the accompanying abstracts.

"The moment of inertia of the vibrating magnet was determined by observing a

* "The number obtained for the force of the earth's magnetism expresses the ratio which that force bears to the *unit of force*, the unit of force being that which, acting on the unit of *mass*, through the unit of *time*, generates in it the unit of *velocity*. These units are entirely arbitrary; but for the sake of convenience in comparison, it is desirable that they should be the same in all the observations which shall be made according to this system. For the unit of mass, then, we may take a *grain*; for the unit of time a *second*; and, if a *foot* be taken as the unit of space, the unit of velocity will be that of one foot per second.

"As the magnetic force operates effectively only on the free or uncombined elements of the magnetic fluid, we are to understand by the earth's magnetic force, its action on the elementary unit of free magnetism; and we must take for that unit the quantity of free magnetism, which, acting on another equal quantity at the unit of distance, exerts an effect equal to the unit of force already defined."—*Royal Society, Report of the Committee of Physics, &c., approved by the President and Council,* 1840, pp. 21, 22.

second series of vibrations with two cylinders of equal weight and dimensions suspended across the end of the bar, in the manner described by M. WEBER. The times of vibration are uncorrected for the torsion of the suspension thread, or for the changes of horizontal intensity occurring during the intervals of the experiments.

"Abstract of Observations of the absolute Horizontal Intensity.

1842.	No. of Magnet.	Experiments of Deflection.									Times of vibration.			Values of		
		Distances in feet.				Angles of Deflection.				Log of $\frac{m}{X}$.	Without weights.	With weights.	Log of mX.	X.	m.	Temp. of Magn.
						° ′	° ′	° ′	° ′		s	s				°
May 26.	10	1·4746	....	1·8671	....	7 56·8	....	3 56·0	....	9·34969	6·218	11·630	0·49070	3·7196	0·832	62
28.	15	1·4832	....	1·8668	....	7 20·5	....	3 42·0	....	9·32349	6·433	....	0·46439	·7192	·783	63
28.	13	1·4831	....	1·8669	....	7 20·7	....	3 41·9	....	9·32296	6·442	....	0·46410	·7202	·783	62
30.	13	1·4831	1·5164	1·8669	1·9086	7 17·4	6 48·9	3 40·4	3 26·0	9·31982	6·481	12·078	0·45885	·7112	·775	67
30.	15	1·4165	1·4832	1·9085	1·9668	8 23·0	7 18·1	3 27·0	3 09·3	9·32244	6·433	12·000	0·46439	·7237	·782	68

From these experiments we may regard 3·72 as the approximate value of the horizontal force at Woolwich at the period referred to; and 3·72 + e as the corrected value at the same station, corresponding to the period which shall hereafter be taken as the epoch of the magnetic maps of the globe, which these and similar contributions will combine to form,—e being a small quantity depending partly on the epoch, and partly on the possibly increased precision of determinations hereafter to be made with improved apparatus. In the mean time 3·72 has been adopted, and will continue to be used, as the provisional value of the horizontal force at Woolwich; and the intensities at Sir EDWARD BELCHER's stations have been computed and are expressed accordingly.

The general table of the determinations of the horizontal force (Table I.) is divided into three portions. Part I. contains a condensed abstract of the observations with Nos. 5, 6, 7 and 8, antecedent to March 1839, at several of the ports of the west coast of America. The column entitled "corrected times," shows the mean times of vibration corrected for the chronometer's rate and for the arc of vibration, and reduced to a mean temperature of 75°; employing for that purpose the coefficients found experimentally for each needle. The corrections for the arc of vibration have been made by multiplying the time of vibration by $1 - \frac{a\,a'}{16}$, a and a' being the sines of the semiarcs at the commencement and conclusion of the observation. Previous to March 1839, the commencing semiarc was always 40°; subsequent to that period always 20°. The concluding arcs are specified in the Table. Panama is here employed as a base station; and the means of the corrected times in March 1837, October 1838, and March 1839, have been taken, for each needle respectively, as the approximate times throughout the interval; the values of the horizontal force are given in reference to the scale of absolute measure, the force at Panama being taken as = 7·743 (Part II. of Table I. of this memoir).

Part II. contains a condensed abstract of the observations with Nos. 5, 6, 7, 8, 9, 11, 12 and 13, between March 1839 and April 1840, more detailed particulars of which have been already given in Table V. of No. II. of these Contributions. Part III. comprises the whole remainder of the observations from May 1840 at Rarotonga Island to December 1842 at Woolwich. The manner in which the values of the horizontal force in the final column of Parts II. and III. have been computed, has been already explained.

Table II. contains the observations of the Inclination subsequent to March 1840, made with the same six-inch Inclinometer, by Robinson, employed at the earlier stations: this Table is a continuation of Table IX. in No. II. of these Contributions.

The Declinations inserted in the general table were observed with a nine-inch altitude and azimuth instrument by Cary, having a four-inch magnetic needle attached to it.

The general table, Table III., comprises in one view, the Declination, Inclination, horizontal and total Intensity, resulting from the whole of the observations, and is the best evidence, especially to those who are familiar with the practical details of such observations, of the amount of obligation which magnetical science owes to Sir Edward Belcher, and to the officers of the Royal Navy employed under his direction.

Table I.—Part I.

Abstract of Observations with the Intensity Needles between March 1837 and March 1839; in these observations the commencing semi-arc was 40°.

Station.	1837.	Needle.	No. of observations.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity. Panama = 7·743.
				s	°	s	°	s	
Panama ..	March 10.	5	2	472·7	79	L. 1·1	14	467·8	
	10.	6	2	512·5	76	L. 1·1	14	507·4	
	12.	7	1	522·7	71	L. 1·1	4	531·3	
	12.	8	1	470·4	76	L. 1·1	7	468·1	
Fort Etches	August 28.	5	1	736·7	50	L. 8·6	5	737·9	3·13 } 3·15
	28.	6	1	792·4	50	L. 8·6	8	794·2	3·16
	1838.								
Acapulco ..	January 17.	6	1	508·1	88	L. 5·4	13	501·4	7·94 } 7·91
	17.	7	1	530·7	91	L. 5·4	3	529·2	7·87
Callao	June 20 & 21.	5	80	487·1	68	L. 2·0	14	483·1	7·31
	25.	6	1	525·0	79	L. 2·0	13	519·2	7·41 } 7·37
	27.	7	1	546·1	72	L. 2·0	5	544·3	7·44
	27.	8	1	483·8	70	L. 2·0	6·5	481·8	7·32
Puna Island, Guayaquil	Sept. 3.	5	90	476·1	78	L. 1·4	14	471·2	7·69 } 7·74
	17–23.	6	7	513·2	89	L. 1·4	13	505·9	7·80
Panama ..	October 28.	5	2	475·3	82	Not recorded.	14	470·0	
	28.	6	2	514·6	83	Not recorded.	13	508·3	
	28.	7	1	536·8	83	Not recorded.	4	535·1	
	28.	8	1	471·4	83	Not recorded.	6	469·1	
	1839.								
	March 16.	5	2	476·2	85	L. 2·1	14	470·7	
	16.	7	2	536·1	84	L. 2·1	3·5	534·5	
	16.	8	2	471·4	87	L. 2·1	5	469·4	

Table I.—Part II.

Abstract of Observations with the Intensity Needles between March 1839 and April 1840; in these observations the commencing semi-arc was 20°.

Station.	1839.	Needle.	No. of observations.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
				s	°	s	°	s		
Panama	March 16.	5	2	472·45	85	L. 2·1	7·5	470·2	7·731	
	16.	6	3	522·80	87	L. 2·1	6·2	519·7		
	16.	7	3	534·53	85	L. 2·1	2·0	533·6	7·727	
	16.	8	3	469·30	87	L. 2·1	2·5	468·5		7·743
	16.	9	3	436·85	83	L. 2·1	2·7	436·2	7·763	
	16.	11	1	473·26	87	L. 2·1	2·5	472·2	7·745	
	16.	12	1	403·22	87	L. 2·1	3·5	402·4	7·726	
	16.	13	1	393·24	88	L. 2·1	3·5	392·2	7·768	
Cocos Island	April 8.	5	2	466·68	82	L. 2·5	5·7	465·0	7·907	
	8.	6	2	514·77	81	L. 2·5	7·0	512·3		
	8.	11	2	465·68	78	L. 2·5	3·0	465·0	7·988	7·924
	8.	12	2	397·43	77	L. 2·5	3·0	396·9	7·939	
	8.	13	2	390·00	78	L. 2·5	3·7	389·3	7·864	
Oahu	June 4–9.	5	4	513·89	87	L. 1·3	5·7	511·4	6·536	
	5–9.	6	4	575·77	86	L. 1·3	5·0	572·6		
	8.	11	2	515·65	83	L. 1·3	2·2	514·7	6·518	6·506
	8.	12	2	439·60	87	L. 1·3	4·0	438·6	6·503	
	8.	13	2	430·55	87	L. 1·3	4·2	429·3	6·467	
Kodiack	July 7.	5	1	688·46	79	L. 2·0	1·5	687·5	3·617	3·635
	7.	6	1	765·08	80	L. 2·0	1·0	763·6	3·653	
Sitka	18.	5	1	730·30	61	L. 0·4	4·0	731·4	3·195	
	18.	6	1	811·20	56	L. 0·4	5·0	814·6		
	18.	11	1	730·40	62	L. 0·4	1·5	730·9	3·231	3·207
	18.	12	1	624·00	64	L. 0·4	1·5	624·1	3·211	
	18.	13	1	611·20	67	L. 0·4	1·5	611·4	3·189	
Woolwich	August 11–13.	7	3	767·35	64	L. 2·0	0·8	767·0	3·742	
	11–13.	8	3	671·17	66	L. 2·0	0·8	670·9		3·746
	11–13.	9	3	627·38	63	L. 2·0	1·0	627·6	3·750	
Fort Vancouver	13.	5	7	617·87	66	G. 8·5	3·5	618 2	4·474	
	13.	6	5	691·60	66	G. 8·5	2·5	692·9		
	13.	11	1	620·67	56	G. 8·5	2·0	621·3	4·475	4·475
	13.	12	2	528·84	74	G. 8·5	2·5	528·3	4·482	
	13.	13	2	517·05	74	G. 8·5	2·7	516·5	4·468	
Baker's Bay	September 13.	5	2	623·40	65	L. 1·9	3·5	623·9	4·392	4·394
	13.	6	2	698·17	69	L. 1·9	2·2	698·9	4·396	
Port Bodega	25.	5	1	560·44	63	L. 2·7	3·5	561·1	5·429	5·440
	25.	6	1	625·88	63	L. 2·7	3·0	627·6	5·452	
San Francisco	30.	5	2	556·98	73	L. 3·4	5·2	556·1	5·528	
	30.	6	2	622·10	62	L. 3·4	5·2	623·4	5·524	5·524
	30.	11	1	558·72	64	L. 3·4	2·0	558·9	5·529	
	30.	12	1	476·36	62	L. 3·4	3·0	476·3	5·515	
Monterey	October 5.	5	1	549·72	65	L. 2·9	4·5	549·9	5·652	5·666
	5.	6	1	613·76	64	L. 2·9	4·0	615·0	5·680	
Santa Barbara	10.	5	1	538·90	77	L. 2·9	5·0	537·7	5·912	5·925
	10.	6	1	602·28	73	L. 2·9	6·0	601·3	5·939	
San Pedro	12.	5	1	538·44	74	L. 2·7	3·0	538·0	5·907	5·913
	12.	6	1	602·56	73	L. 2·7	3·0	602·3	5·920	
San Diego	17.	5	1	528·02	70	L. 2·7	4·5	527·7	6·140	6·142
	17.	6	1	590·55	67	L. 2·7	4·0	591·2	6·145	
San Quentin	24.	5	1	515·30	77	L. 2·7	3·5	514·4	6·454	6·468
	24.	6	1	574·64	65	L. 2·7	4·0	575·6	6·482	
San Bartholomew.	29.	5	1	503·28	73	L. 2·7	5·0	502·6	6·769	6·780
	29.	6	1	562·72	73	L. 2·7	3·5	562·4	6·791	

TABLE. (Continued.)

Station.	1839.	Needle.	No. of observations.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.		
				s	°	s	°	s			
Magdalena Bay	November 1.	5	1	490·08	73	L. 2·7	5·5	489·3	7·141	7·160	
	1.	6	1	547·36	73	L. 2·7	4·0	546·9	7·180		
Bay of San Lucas	21.	5	1	487·90	83	L. 2·7	6·0	486·0	7·238	7·259	
	21.	6	1	545·92	84	L. 2·7	6·0	543·1	7·280		
Mazatlan	28.	5	1	488·08	71	L. 1·9	6·5	487·3	7·200		
	28.	6	1	546·16	71	L. 1·9	6·0	545·6			
	29.	7	1	552·84	73	L. 1·9	2·0	552·5			
	Nov. 30 and Dec. 2.	7	3	558·83	74	L. 1·9	2·0	558·4		7·208	
	Nov. 29 to Dec. 2.	8	4	487·22	74	L. 1·9	3·0	486·7			7·214
		9	3	452·82	74	L. 1·9	3·5	452·2	7·222		
	November 28.	11	1	488·52	72	L. 1·9	2·0	488·3	7·245		
	28.	12	1	416·94	72	L. 1·9	3·0	416·6	7·208		
	28.	13	1	407·28	72	L. 1·9	3·5	406·9	7·200		
San Blas	Dec. 6. and 19.	5	2	482·42	83	L. 1·9	4·2	480·8	7·394		
	6. and 19.	6	3	539·09	81	L. 1·9	4·2	537·2			
	6. and 19.	7	3	551·30	80	L. 1·9	2·0	550·7	7·410		
	6. and 19.	8	2	481·14	82	L. 1·9	2·5	480·4			
	6. and 19.	9	2	446·04	81	L. 1·9	2·5	445·4	7·446		7·421
	6. and 19.	11	2	482·92	83	L. 1·9	2·0	482·2	7·429		
	6. and 19.	12	2	410·77	82	L. 1·9	2·2	410·2	7·432		
	6. and 19.	13	2	401·66	82	L. 1·9	2·5	401·0	7·414		
Socorro Island	26.	5	2	477·92	84	L. 3·5	6·5	475·9	7·477		
	26.	6	3	553·78	85	L. 3·5	4·0	551·2			
Clarion Island	29.	5	2	481·70	85	L. 3·5	6·2	479·6	7·597		
	29.	6	2	550·47	84	L. 3·5	5·0	547·9			
	1840.										
Martin's Island	Jan. 23–29.	5	5	478·74	87	L. 3·6	6·0	476·5	7·578		
	23–29.	6	6	543·03	86	L. 3·6	5·0	540·1			
	25–27.	7	2	544·78	87	L. 3·6	2·2	544·1	7·593		
	25–27.	8	2	475·88	85	L. 3·6	2·7	475·1			
	25–27.	8	2	475·88	85	L. 3·6	2·7	475·1			7·594
	25–27.	9	2	441·17	88	L. 3·6	3·2	440·3	7·618		
	25–27.	11	2	477·94	89	L. 3·6	2·0	476·9	7·593		
	25–27.	12	2	406·58	87	L. 3·6	3·0	405·8	7·595		
	25–27.	13	2	397·54	88	L. 3·6	3·7	396·4	7·585		
Bow Island	Feb. 6–29.	5	14	484·2	86	L. 5·3	7·0	482·1	7·402		
	March 20–21.	5	14	484·30	83	G. 5·8	6·5				
	Feb. 6–29.	6	22	547·77	87	L. 5·3	5·5	545·1			
	March 20–21.	6	14	548·53	84	G. 5·8	6·5				
	22.	7	3	551·24	76	G. 5·8	3·0	550·6	7·415		7·425
	22.	8	4	481·55	77	G. 5·8	3·0	480·9			
	22.	9	3	446·47	82	G. 5·8	4·0	445·6	7·440		
	22.	11	3	482·83	85	G. 5·8	2·5	481·9	7·440		
	22.	12	3	411·08	87	G. 5·8	3·0	410·2	7·432		
	22.	13	3	401·97	86	G. 5·8	3·4	400·8	7·419		
Tahiti, Point Venus	Ap. 4 to May 6.	5	11	482·47	84	L. 4·0	6·2	480·4	7·453		
	April 11.	6	11	546·15	83	L. 4·0	5·5	543·6			
	May 6–7.	7	3	548·07	88	L. 3·7	2·3	547·3	7·505		
	6–7.	8	4	479·03	82	L. 3·7	2·7	478·3			
	6–7.	9	3	443·65	81	L. 3·7	3·2	443·0	7·525		7·491
	6.	11	3	480·55	80	L. 3·7	2·6	479·9	7·501		
	6–8.	12	3	409·01	82	L. 3·7	2·7	408·4	7·498		
	6–8.	13	3	400·35	82	L. 3·7	3·2	399·6	7·465		
Tahiti, Papeete	April 17.	5	2	480·13	77	L. 5·2	6·0	479·1	7·498		
	17.	6	2	544·36	84	L. 5·2	5·0	541·8			

Table I.—Part III.

Observations with the Intensity Needles between May 1840 and December 1842; in these observations the commencing semi-arc was 20°.

Stations.	1840.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
Rarotonga Island, Harvey Group.	May 15.	5	486·34	77	L. 5·8	7·0	484·9	7·315	
	15.	5	486·46	80	L. 5·8	6·5			
	15.	6	555·48	85	L. 5·8	5·5	552·6		
	15.	6	555·40	85	L. 5·8	5·0			
Vavao Island, Hapae Group.	22.	5	474·16	77	L. 5·6	6·5			
	22.	5	473·68	77	L. 5·6	7·5	472·4	7·706	
	22.	5	473·92	78	L. 5·6	7·0			
	22.	6	530·88	78	L. 5·6	6·5			
	22.	6	529·96	77	L. 5·6	6·5	528·7		
	22.	6	530·24	76	L. 5·6	7·0			
Nukulau Island, Feejee Group.	30.	5	474·00	80	L. 5·6	6·5			
	30.	5	473·76	80	L. 5·6	6·5	472·2	7·715	
	30.	5	474·08	85	L. 5·6	6·5			
	30.	6	532·74	85	L. 5·6	6·0			
	30.	6	533·14	83	L. 5·6	5·5			
	30.	6	532·24	82	L. 5·6	6·0	530·4		
	30.	6	532·60	79	L. 5·6	7·0			
	31.	7	540·46	80	L. 5·6	2·5			
	31.	7	540·00	80	L. 5·6	2·5	540·0	7·676	
	June 1.	7	541·46	79	L. 5·6	3·0			
	1.	8	472·68	79	L. 5·6	3·5			
	1.	8	472·70	79	L. 5·6	3·5	472·0		
	1.	8	472·88	80	L. 5·6	3·5			7·708
	1.	9	440·12	85	L. 5·6	3·5			
	1.	9	439·52	86	L. 5·6	3·5	438·8	7·738	
	1.	9	439·34	86	L. 5·6	3·5			
	May 30.	11	474·60	81	L. 5·6	3·0			
	31.	11	474·32	86	L. 5·6	2·5	473·7	7·697	
	31.	11	474·72	85	L. 5·6	3·0			
	31.	12	403·10	85	L. 5·6	3·0			
	31.	12	403·68	86	L. 5·6	3·5	402·7	7·715	
	31.	12	403·32	85	L. 5·6	3·0			
	31.	13	394·52	82	L. 5·6	4·0			
	31.	13	395·14	82	L. 5·6	3·5	394·1	7·706	
	31.	13	394·96	82	L. 5·6	3·5			
Banga Island, Feejee Group.	June 15.	5	474·32	89	L. 6·0	5·5	472·0	7·721	7·718
	15.	6	533·36	91	L. 6·0	4·0	529·9	7·715	
Tanna Island, Port Resolution, New Hebrides.	22.	5	470·62	75	L. 6·2	6·5			
	22.	5	470·44	72	L. 6·2	6·5	469·7	7·797	
	22.	5	470·76	72	L. 6·2	7·0			
	22.	6	527·80	72	L. 6·2	6·0			7·790
	22.	6	527·40	70	L. 6·2	5·5	527·5	7·784	
	22.	6	528·26	70	L. 6·2	6·0			
Cocos Island, Port Carteret, New Ireland.	July 7.	5	464·16	77	L. 6·3	7·5			
	7.	5	463·72	77	L. 6·3	8·0	462·6	8·039	
	15.	5	463·92	78	L. 6·3	7·0			
	7.	6	520·73	79	L. 6·3	7·0			
	7.	6	520·40	79	L. 6·3	7·0	518·9		
	15.	6	521·44	78	L. 6·3	6·5			
	7.	7	529·20	80	L. 6·3	3·5			
	7.	7	529·44	81	L. 6·3	3·5	528·4	8·049	
	15.	7	528·98	77	L. 6·3	3·5			8·039

TABLE. (Continued.)

Station.	1840.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° FAHR.	Horizontal Intensity.	
			s	°	s	°	s		
Cocos Island, Port Carteret, New Ireland.	July 7.	8	463·64	83	L. 6·3	3·5			8·039
	7.	8	463·68	84	L. 6·3	4·0	463·0		
	7.	8	463·68	80	L. 6·3	4·0			
	15.	8	464·26	77	L. 6·3	4·0			
	7.	9	430·84	83	L. 6·3	5·5			
	7.	9	430·88	85	L. 6·3	5·0	430·0	8·060	
	7.	9	431·16	82	L. 6·3	4·5			
	15.	9	430·88	77	L. 6·3	5·0			
	7.	11	464·54	85	L. 6·3	3·5			
	7.	11	464·76	85	L. 6·3	3·5	463·7	8·033	
	7.	11	464·84	81	L. 6·3	3·0			
	7.	12	395·42	84	L. 6·3	4·0			
	7.	12	395·96	84	L. 6·3	4·0	394·8	8·024	
	7.	12	395·54	81	L. 6·3	5·0			
	7.	13	386·60	84	L. 6·3	4·0			
	7.	13	387·16	83	L. 6·3	4·0	386·1	8·028	
	7.	13	387·16	82	L. 6·3	4·5			
Britannia Island, New Guinea.	27.	5	470·12	77	L. 6·2	8·0			
	27.	5	469·64	77	L. 6·2	7·5	468·5	7·835	
	27.	5	470·43	78	L. 6·2	7·5			7·832
	27.	6	527·54	78	L. 6·2	6·5			
	27.	6	527·84	78	L. 6·2	7·0	525·9	7·828	
	27.	6	527·76	78	L. 6·2	6·5			
Booby Rock, Jobie Island, New Guinea.	August 8.	5	463·80	83	L. 6·2	6·5			
	8.	5	465·62	83	L. 6·2	8·0			
	8.	5	464·24	82	L. 6·2	7·0	402·2	8·053	
	8.	5	463·16	83	L. 6·2	7·0			
	8.	5	463·88	84	L. 6·2	7·0			
	8.	6	520·86	82	L. 6·2	6·5			
	8.	6	521·28	85	L. 6·2	6·5	518·5		
	8.	6	521·16	83	L. 6·2	6·0			
	8.	7	529·24	84	L. 6·2	3·0	528·6	8·045	
	8.	7	529·40	82	L. 6·2	3·0			
	8.	8	463·08	82	L. 6·2	3·5			
	8.	8	462·92	82	L. 6·2	3·5	462·2		
	8.	8	463·08	82	L. 6·2	3·5			8·056
	8.	9	429·64	80	L. 6·2	5·5			
	8.	9	430·12	80	L. 6·2	5·0	429·0	8·093	
	8.	9	430·36	82	L. 6·2	5·5			
	8.	11	463·24	82	L. 6·2	3·0			
	8.	11	463·04	82	L. 6·2	3·0	462·2	8·067	
	8.	11	462·96	82	L. 6·2	3·5			
	8.	12	395·14	82	L. 6·2	4·0			
	8.	12	395·05	81	L. 6·2	4·0	394·4	8·041	
	8.	12	395·10	81	L. 6·2	4·0			
	8.	13	386·96	81	L. 6·2	4·5			
	8.	13	386·44	81	L. 6·2	4·0	385·9	8·036	
	8.	13	386·84	81	L. 6·2	4·5			
Shell Rock, Jobie Island.	14.	5	463·88	86	L. 5·8	5·5	461·4	8·079	
	14.	5	463·62	92	L. 5·8	6·0			8·066
	14.	6	522·32	91	L. 5·8	5·5	518·8	8·054	
	14.	6	522·38	89	L. 5·8	6·0			
Amsterdam Island, New Guinea.	24.	5	464·68	86	L. 5·8	7·0			
	24.	5	464·36	86	L. 5·8	7·0	462·7	8·036	
	24.	5	465·44	87	L. 5·8	6·5			
	24.	5	464·84	82	L. 5·8	7·5			8·012
	24.	6	522·72	81	L. 5·8	6·5			
	24.	6	522·60	87	L. 5·8	6·5	521·0	7·988	
	24.	6	523·12	88	L. 5·8	6·0			

TABLE. (Continued.)

Station.	1840.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
Fort Defence, Bouro Island.	August 31.	5	463·28	89	L. 6·4	6·0	461·2	8·088	
	Sept. 1.	5	463·36	85	L. 6·4	6·5			8·093
	August 31.	6	521·52	89	L. 6·4	5·0	517·4	8·097	
	Sept. 1.	6	520·08	89	L. 6·4	6·0			
Fort Victoria, Amboyna Island.	4.	5	460·65	76	L. 6·1	8·0			
	4.	5	461·08	80	L. 6·1	8·0	459·1	8·161	
	4.	5	460·28	77	L. 6·1	7·5			
	4.	6	518·04	76	L. 6·1	6·5			
	4.	6	517·96	78	L. 6·1	7·0	516·2		
	4.	6	517·78	79	L. 6·1	6·0			
	5.	7	525·30	84	L. 6·1	3·0			
	5.	7	525·80	84	L. 6·1	2·5	525·0	8·157	
	5.	7	526·00	86	L. 6·1	2·0			
	5.	8	461·40	86	L. 6·1	2·5			
	5.	8	460·80	87	L. 6·1	2·5	460·1		8·144
	5.	8	460·32	87	L. 6·1	2·5			
	5.	9	427·60	84	L. 6·1	3·0			
	5.	9	428·04	77	L. 6·1	3·0	427·2	8·163	
	5.	9	427·93	77	L. 6·1	4·5			
	5.	11	463·32	80	L. 6·1	3·0			
	5.	11	463·42	85	L. 6·1	2·5	462·6	8·136	
	5.	11	463·36	85	L. 6·1	2·5			
	5.	12	392·72	84	L. 6·1	3·0	392·1	8·134	
	4.	13	385·48	81	L. 6·1	4·0			
	4.	13	384·56	82	L. 6·1	4·0	384·0	8·116	
	5.	13	384·50	84	L. 6·1	4·0			
Fort Rotterdam, Macassar Island.	26.	5	465·00	73	L. 6·2	8·0			
	27.	5	464·34	78	L. 6·2	7·0	463·1	8·021	
	27.	5	464·44	78	L. 6·2	7·0			
	30.	5	464·80	87	L. 6·2	6·0			
	26.	6	522·20	74	L. 6·2	7·0			
	27.	6	523·28	79	L. 6·2	6·5	521·2		
	27.	6	523·04	79	L. 6·2	6·5			
	27.	7	530·50	83	L. 6·2	2·5	530·1	8·023	
	27.	7	531·00	83	L. 6·2	2·0			
	28.	8	464·96	72	L. 6·2	3·0	464·1		8·029
	28.	8	464·20	72	L. 6·2	3·5			
	28.	9	431·21	90	L. 6·2	3·5	430·1	8·054	
	28.	9	430·76	90	L. 6·2	3·0			
	29.	11	466·92	91	L. 6·2	2·0	465·6	8·032	
	29.	11	466·46	91	L. 6·2	2·5			
	29.	12	395·86	90	L. 6·2	3·0	395·1	8·014	
	29.	12	395·84	90	L. 6·2	2·5			
	29.	13	388·32	89	L. 6·2	3·5	387·6	8·031	
	29.	13	388·76	87	L. 6·2	3·0			
Solombo Island.	October 4.	5	466·72	91	L. 6·2	6·5			
	4.	5	466·92	92	L. 6·2	6·5	464·1	7·988	
	4.	5	466·86	94	L. 6·2	6·5			8·003
	4.	6	525·92	92	L. 6·2	5·0			
	4.	6	525·48	92	L. 6·2	5·5	521·8	8·019	
	4.	6	526·00	94	L. 6·2	5·5			
Rendezvous Island, Pulo Kumpal (S.W. P[t] of Borneo).	7.	5	466·16	85	L. 6·6	8·0			
	7.	5	466·07	84	L. 6·6	7·5	462·4	8·047	
	7.	5	466·17	82	L. 6·6	7·0			8·038
	7.	6	524·56	85	L. 6·6	7·0			
	7.	6	524·45	85	L. 6·6	7·0	521·5	8·029	
	7.	6	524·47	84	L. 6·6	7·0			

TABLE. (Continued.)

Station.	1840.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° FAHR.	Horizontal Intensity.	
			s	°	s	°	s		
Singapore	October 18.	5	466·61	79	L. 6·8	7·0	465·6	7·935	7·940
	18.	5	467·06	70	L. 6·8	7·5			
	18.	6	524·88	70	L. 6·8	7·5	524·7		
	18.	7	532·60	75	L. 6·8	3·0	532·3	7·957	
	18.	7	533·02	75	L. 6·8	2·5			
	18.	8	467·30	79	L. 6·8	3·5	466·8		
	18.	8	467·56	79	L. 6·8	3·5			
	18.	8	467·54	80	L. 6·8	3·5			
	18.	9	433·80	82	L. 6·8	3·5	432·7	7·958	
	18.	9	433·46	84	L. 6·8	3·5			
	18.	9	432·97	83	L. 6·8	3·5			
	18.	11	468·97	77	L. 6·8	3·0	468·7	7·926	
	18.	11	469·48	78	L. 6·8	2·5			
	18.	12	397·28	79	L. 6·8	3·0	396·6	7·953	
	18.	12	396·88	80	L. 6·8	3·0			
	18.	12	397·28	82	L. 6·8	3·0			
	18.	13	391·36	83	L. 6·8	3·0	390·0	7·910	
	18.	13	390·98	84	L. 6·8	3·5			
	18.	13	390·28	85	L. 6·8	3·5			
Manila	Dec. 1.	5	469·64	82	G. 11·5	7·0	468·2	7·848	7·869
	1.	5	469·52	82	G. 11·5	7·0			
	1.	5	469·54	80	G. 11·5	7·0			
	1.	5	469·44	80	G. 11·5	7·0			
	1.	5	470·92	80	G. 11·5	5·0			
	2.	5	470·40	83	G. 11·5	5·0			
	1.	6	530·72	82	G. 11·5	6·5	528·1	7·891	
	2.	6	530·70	84	G. 11·5	5·5			
Island of Sampan-chow, Boca Tigris	30.	5	476·04	70	L. 5·9	6·0	475·6	7·606	7·608
	30.	5	476·32	72	L. 5·9	6·0			
	31.	5	475·94	69	L. 5·9	6·0			
	30.	6	538·60	73	L. 5·9	4·0	537·8	7·611	
	30.	6	538·14	76	L. 5·9	5·0			
	31.	6	537·81	68	L. 5·9	5·5			
	1841.								
Island of Hong Kong.	Feb. 12.	5	475·82	70	L. 5·7	6·0	475·2	7·616	7·574
	12.	5	475·80	71	L. 5·7	6·0			
	12.	5	476·36	74	L. 5·7	6·0			
	12.	6	541·60	72	L. 5·7	5·0	540·5	7·532	
	12.	6	541·68	73	L. 5·7	5·5			
	12.	6	540·46	73	L. 5·7	6·5			
Sampanchow Island.	20.	5	476·04	64	L. 6·4	6·5	475·6	7·606	7·613
	20.	5	476·13	74	L. 6·4	5·5			
	20.	5	476·44	76	L. 6·4	6·0			
	20.	6	537·40	67	L. 6·4	5·0	537·4	7·621	
	20.	6	538·12	76	L. 6·4	5·0			
	20.	6	538·64	76	L. 6·4	5·5			
Macao	April 9.	5	478·04	84	L. 6·4	6·5	475·7	7·600	7·596
	9.	5	477·90	83	L. 6·4	6·5			
	9.	5	477·48	83	L. 6·4	7·5			
	9.	6	542·38	89	L. 6·4	5·5	538·9		
	9.	6	542·70	92	L. 6·4	6·0			
	9.	6	542·32	86	L. 6·4	5·5			
	9.	7	544·60	85	L. 6·4	2·5	543·5	7·632	
	9.	7	544·42	86	L. 6·4	3·0			
	9.	7	544·03	88	L. 6·4	2·5			
	9.	8	478·16	87	L. 6·4	3·0	477·3		
	9.	8	477·92	84	L. 6·4	3·5			
	9	8	478·44	85	L. 6·4	3·0			

Table. (Continued.)

Station.	1841.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
Macao.	April 9.	9	442·94	85	L. 6·4	2·5			7·596
	9.	9	442·96	85	L. 6·4	2·5	442·3	7·653	
	9.	9	442·92	82	L. 6·4	3·0			
	9.	11	480·40	83	L. 6·4	3·5			
	9.	11	480·20	83	L. 6·4	3·0	479·5	7·538	
	9.	11	480·36	73	L. 6·4	3·0			
	9.	12	405·88	73	L. 6·4	3·5			
	9.	12	405·36	73	L. 6·4	3·0	405·5	7·606	
	9.	12	406·44	73	L. 6·4	3·5			
	9.	13	400·48	73	L. 6·4	4·0			
	9.	13	400·16	74	L. 6·4	3·5	399·7	7·548	
	9.	13	400·04	74	L. 6·4	3·5			
	12.	5	476·84	73	G. 18·2	6·5			
	12.	5	475·84	71	G. 18·2	7·5	475·2	7·618	
	12.	5	476·10	71	G. 18·2	7·5			
	12.	6	539·20	72	G. 18·2	6·5			
	12.	6	539·13	72	G. 18·2	6·0	538·2		
	12.	6	538·86	73	G. 18·2	6·0			
	19.	7	544·28	79	L. 6·4	2·0			
	20.	7	544·38	81	L. 6·4	3·0	543·8	7·625	
	20.	7	544·40	81	L. 6·4	2·0			
	20.	8	478·68	81	L. 6·4	3·0			
	20.	8	478·06	83	L. 6·4	3·0	477·6		
	20.	8	478·08	83	L. 6·4	2·0			
	21.	9	443·72	80	L. 6·4	3·5			7·595
	21.	9	443·56	83	L. 6·4	4·0	443·0	7·630	
	21.	9	443·88	83	L. 6·4	3·5			
	13.	11	479·58	68	G. 18·2	2·0			
	13.	11	478·82	69	G. 18·2	2·0	479·0	7·553	
	13.	11	479·28	70	G. 18·2	2·0			
	13.	12	405·40	70	G. 18·2	2·5			
	13.	12	405·36	71	G. 18·2	2·5	405·3	7·615	
	13.	12	406·26	71	G. 18·2	3·0			
	19.	13	400·80	79	L. 6·4	3·5			
	19.	13	400·68	79	L. 6·4	3·0	400·0	7·540	
	19.	13	400·42	80	L. 6·4	4·0			
Island of Sampan-chow.	May 8.	5	476·74	65	L. 5·4	7·5	476·4	7·581	
	8.	5	476·60	65	L. 5·4	7·5			
	8.	6	539·26	66	L. 5·4	6·5	539·1	7·606	7·593
	8.	6	538·88	66	L. 5·4	7·0			
	August 19.	5	477·56	88	L. 8·1	7·0			
	19.	5	477·48	85	L. 8·1	7·5	474·9	7·630	
	19.	5	476·86	89	L. 8·1	7·5			
	19.	6	543·0	89	L. 8·1	6·5			
	19.	6	543·38	89	L. 8·1	6·5	538·8		
	19.	6	543·28	89	L. 8·1	7·0			
	Sept. 24.	5	477·02	83	L. 8·1	7·0	474·7	7·634	
	24.	5	476·52	85	L. 8·1	7·0			
	24.	6	545·62	85	L. 8·1	6·5			
	24.	6	545·60	85	L. 8·1	6·5	542·6		
	24.	6	544·24	78	L. 8·1	6·5			
	24.	7	543·36	78	L. 8·1	2·5	542·8	7·651	
	24.	7	543·38	78	L. 8·1	2·5			
	25.	8	477·66	83	L. 8·1	3·5	476·6		
	25.	8	477·16	83	L. 8·1	3·5			
	25.	9	443·40	84	L. 8·1	3·5	442·5	7·644	
Macao	25.	9	443·20	85	L. 8·1	3·5			7·634*

Table. (Continued.)

Station.	1841.	Needle.	Time of vibration.	Thermo-meter.	Chronometer rate.	Final semi-arc.	Corrected time 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
Macao...........	Sept. 25.	11	476·84	85	L. 8·1	3·0	475·5	7·665	7·634 *
	25.	11	476·20	85	L. 8·1	3·5			
	25.	12	405·96	85	L. 8·1	3·0	405·2	7·616	
	25.	12	405·88	85	L. 8·1	3·0			
	25.	13	399·52	84	L. 8·1	4·0	398·4	7·597	
	25.	13	399·26	84	L. 8·1	4·0			
	Nov. 16.	5	475·90	66	G. 20·2	8·0			
	16.	5	476·14	67	G. 20·2	8·0	475·3	7·616	
	16.	5	475·92	67	G. 20·2	7·5			
	16.	6	537·20	67	G. 20·2	7·0	536·8		
	16.	6	536·74	67	G. 20·2	7·0			
	19.	7	547·58	62	G. 19·0	2·5			
	19.	7	547·96	62	G. 19·0	2·5			
	19.	7	548·12	63	G. 19·0	2·5	547·0	7·537	
	20.	7	545·40	70	L. 6·7	2·5			
	19.	8	479·32	63	G. 19·0	3·0			
	19.	8	479·52	64	G. 19·0	3·0	478·6		
	20.	8	477·92	70	L. 6·7	3·0			
	19.	9	445·05	64	G. 19·0	3·5			7·585
	19.	9	444·92	64	G. 19·0	3·5	444·1	7·575	
	20.	9	443·64	70	L. 6·7	3·0			
	19.	11	476·92	64	G. 19·0	3·5			
	19.	11	477·28	64	G. 19·0	3·0	476·5	7·634	
	20.	11	476·02	70	L. 6·7	2·0			
	19.	12	407·36	64	G. 19·0	3·5			
	19.	12	407·40	64	G. 19·0	3·0	406·9	7·611	
	20.	12	406·80	70	L. 6·7	2·5			
	19.	13	400·80	64	G. 19·0	4·0			
	19.	13	400·76	64	G. 19·0	5·0	400·0	7·536	
	20.	13	399·40	70	L. 6·7	3·0			
	Dec. 8.	5	465·52	84	L. 8·2	6·5			
	8.	5	466·00	83	L. 8·2	7·0			
	9.	5	467·65	86	L. 8·2	7·0			
	9.	5	467·62	86	L. 8·2	6·0			
	11.	5	467·92	86	L. 8·2	5·5	465·1	7·951	
	11.	5	467·48	87	L. 8·2	6·0			
	14.	5	467·32	86	L. 8·2	6·5			
Singapore	14.	5	467·80	85	L. 8·2	6·5			7·961

* The 24th and 25th of September were days of great and general magnetic disturbance. If we collect in one view the determinations of the horizontal force at Macao, we find them as follows:—

1841. April 9 .... six needles — 7·596
April 12–19 .... six needles — 7·595
September 24 and 25 six needles — 7·634
November 16–20 .... six needles — 7·585.

The comparison of these results leaves little reason to doubt that the discrepancy on the 24th and 25th of September was occasioned by an irregularity in the horizontal force itself; and we may infer that the derangement, which was felt at all stations at which magnetic observations were made on that day, was characterized at Macao by an increase of the horizontal force at the hours when Sir Edward Belcher's observations were made. These hours appear to have been, late in the afternoon of the 24th, and from 11 a.m. to 3 p.m. on the 25th.

TABLE. (Continued.)

Station.	1841.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° FAHR.	Horizontal Intensity.	
			s	°	s	°	s		
Singapore	Dec. 8.	6	527·94	83	L. 8·2	6·5			7·961
	8.	6	527·10	84	L. 8·2	6·5			
	9.	6	528·72	88	L. 8·2	7·0			
	9.	6	529·08	88	L 8·2	6·0			
	11.	6	532·45	89	L. 8·2	4·5	527·3		
	11.	6	533·03	90	L. 8·2	7·0			
	11.	6	533·12	88	L. 8·2	5·0			
	11.	6	533·22	88	L. 8·2	3·0			
	14.	6	529·34	85	L. 8·2	5·0			
	14.	6	529·72	85	L. 8·2	6·0			
	9.	7	531·72	88	L. 8·2	2·0			
	9.	7	533·03	87	L. 8·2	2·0	531·9	7·970	
	9.	7	533·08	88	L. 8·2	2·0			
	9.	8	466·82	87	L. 8·2	2·5			
	9.	8	467·44	86	L. 8·2	3·5	466·4		
	9.	8	467·48	85	L. 8·2	3·5			
	9.	9	434·08	84	L. 8·2	3·5	433·4	7·971	
	9.	9	434·20	83	L. 8·2	3·5			
	10.	11	468·08	81	L. 8·2	2·5			
	10.	11	468·14	82	L. 8·2	2·5	467·3	7·973	
	10.	11	467·90	82	L. 8·2	2·5			
	10.	12	398·36	87	L. 8·2	3·0			
	10.	12	398·22	88	L. 8·2	2·5	397·5	7·973	
	10.	12	398·04	88	L. 8·2	2·5			
	10.	13	390·84	88	L. 8·2	3·0			
	10.	13	390·82	88	L. 8·2	3·0	390·0	7·931	
	10.	13	391·20	88	L. 8·2	3·0			
Malacca	20.	5	467·44	82	L. 8·2	7·5			
	20.	5	467·30	82	L. 8·2	7·5	465·5	7·939	
	20.	5	467·58	82	L. 8·2	7·5			
	20.	6	529·76	81	L. 8·2	7·0			7·939
	20.	6	529·92	80	L. 8·2	7·0	527·7	7·939	
	20.	6	529·88	80	L. 8·2	6·5			
Penang	30.	5	466·24	81	L. 8·0	8·0			
	30.	5	466·12	81	L. 8·0	8·0	464·4	7·977	
	30.	5	466·52	82	L. 8·0	7·5			
	30.	6	528·76	83	L. 8·0	6·0			
	30.	6	528·92	85	L. 8·0	6·0	526·0		
	30.	6	529·04	87	L. 8·0	6·5			
	31.	7	532·05	89	L. 8·0	2·5	531·3	7·988	
	31.	7	532·08	90	L. 8·0	2·0			
	31.	8	467·04	90	L. 8·0	3·0	466·3		
	31.	8	467·52	89	L. 8·0	3·0			
	31.	9	433·16	89	L. 8·0	3·0	432·5	8·003	7·982
	31.	9	433·58	89	L. 8·0	3·5			
	30.	11	468·24	90	L. 8·0	2·5	467·0	7·985	
	30.	11	467·84	90	L. 8·0	2·0			
	31.	12	398·32	89	L. 8·0	3·0			
	31.	12	397·60	89	L. 8·0	3·0	397·2	7·985	
	31.	12	398·14	89	L. 8·0	3·0			
	31.	13	390·24	89	L. 8·0	3·0			
	31.	13	390·54	90	L. 8·0	2·5	389·4	7·955	
	31.	13	390·32	90	L. 8·0	3·0			
	1842.								
Island of Malora, N.W. coast of Sumatra.	Jan. 10.	5	470·04	89	L. 8·0	5·0			
	10.	5	469·28	85	L. 8·0	6·5	467·7	7·866	
	13.	5	470·00	83	L. 8·0	7·5			7·863

TABLE. (Continued.)

Station.	1842.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° FAHR.	Horizontal	Intensity.
			s	°	s	°	s		
Island of Malora, N.W. coast of Sumatra.	January 13.	6	532·56	86	L. 8·0	5·5	529·7	7·871	7·863
	13.	6	532·76	85	L. 8·0	6·0			
	13.	6	532·82	83	L. 8·0	6·5			
	13.	6	531·68	81	L. 8·0	6·0			
	13.	11	469·96	81	L. 8·0	2·0	469·2	7·873	
	14.	11	469·60	80	L. 8·0	2·0			
	14.	12	400·20	82	L. 8·0	2·0	400·2	7·869	
	14.	12	401·20	85	L. 8·0	3·0			
	14.	13	393·25	87	L. 8·0	3·0	392·4	7·834	
	14.	13	393·32	86	L. 8·0	3·5			
Acheen Island, North coast of Sumatra.	11.	5	470·72	83	L. 8·0	7·0			
	11.	5	470·44	83	L. 8·0	7·0	468·5	7·837	
	11.	5	470·32	84	L. 8·0	7·5			
	12.	6	532·98	76	L. 8·0	6·0			7·828
	12.	6	532·96	76	L. 8·0	6·0			
	12.	6	533·00	76	L. 8·0	6·5	531·5	7·819	
	12.	6	532·88	79	L. 8·0	6·5			
Point de Galle, Ceylon.	24.	5	472·80	79	L. 8·0	7·5			
	24.	5	472·60	80	L. 8·0	7·5	471·1	7·753	
	24.	5	472·94	81	L. 8·0	7·5			
	24.	6	536·04	83	L. 8·0	7·0			
	24.	6	535·92	84	L. 8·0	6·5	533·1		
	24.	6	536·00	83	L. 8·0	7·0			
	24.	6	535·44	82	L. 8·0	7·0			
	24.	7	540·96	82	L. 8·0	2·5			
	24.	7	540·56	82	L. 8·0	2·0	540·2	7·727	
	24.	7	540·80	82	L. 8·0	2·0			
	24.	8	473·52	82	L. 8·0	3·0	473·0		
	24.	8	473·96	82	L. 8·0	3·5			7·756
	25.	9	439·80	79	L. 7·8	4·0			
	25.	9	439·60	83	L. 7·8	3·5	439·0	7·768	
	25.	9	439·91	83	L. 7·8	3·5			
	25.	11	474·20	90	L. 7·8	2·0			
	25.	11	474·12	91	L. 7·8	2·0	473·0	7·783	
	25.	11	473·90	91	L. 7·8	2·0			
	25.	12	404·04	93	L. 7·8	2·5			
	25.	12	403·98	93	L. 7·8	2·5	403·1	7·753	
	25.	12	403·92	90	L. 7·8	3·0			
	25.	13	395·52	88	L. 7·8	3·5	394·4	7·753	
	25.	13	395·30	88	L. 7·8	3·0			
St. Anne's Island, Seychelles.	Feb. 21.	5	511·04	79	L. 7·3	7·0			
	21.	5	511·00	80	L. 7·3	7·0	509·1	6·636	
	21.	5	511·16	80	L. 7·3	7·0			
	21.	6	579·44	83	L. 7·3	6·0			
	21.	6	579·36	83	L. 7·3	6·0	576·8		
	21.	6	579·60	83	L. 7·3	6·0			
	21.	7	584·12	84	L. 7·3	1·5			
	21.	7	584·12	84	L. 7·3	2·0	583·4	6·623	
	21.	7	583·98	83	L. 7·3	2·0			
	21.	8	512·44	84	L. 7·3	2·0			
	21.	8	512·12	84	L. 7·3	2·5	511·5		
	21.	8	512·20	84	L. 7·3	3·0			
	22.	9	476·08	80	L. 7·3	3·0			
	22.	9	476·32	81	L. 7·3	3·0	475·6	6·647	
	22.	9	476·24	81	L. 7·3	3·0			
	21.	11	511·88	83	L. 7·3	2·0			
	21.	11	512·26	83	L. 7·3	2·0	511·5	6·655	
	21.	11	512·64	82	L. 7·3	2·0			6·632

TABLE. (Continued.)

Station.	1842.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
St. Anne's Island, Seychelles.	Feb. 21.	12	436·72	82	L. 7·3	2·0			6·632
	21.	12	437·00	83	L. 7·3	3·0	436·3	6·633	
	21.	12	437·04	82	L. 7·3	3·0			
	21.	13	428·40	83	L. 7·3	3·0			
	21.	13	428·36	82	L. 7·3	3·0	427·5	6·601	
	21.	13	428·12	83	L. 7·3	3·5			
Sandy Point, Majambo Bay, Madagascar.	March 14.	5	571·52	87	L. 8·4	5·5			
	14.	5	571·28	89	L. 8·4	5·0	568·6	5·500	
	14.	5	571·66	90	L. 8·4	5·0			
	15.	5	570·60	90	G. 8·4	4·5			
	14.	6	641·16	82	L. 8·4	4·0			
	14.	6	640·39	82	L. 8·4	5·0	637·9		
	14.	6	643·29	93	L. 8·4	4·5			
	15.	6	640·96	91	G. 8·4	4·5			
	14.	7	650·36	92	L. 8·4	1·0			
	14.	7	650·56	90	L. 8·4	1·0	650·1	5·480	
	14.	7	651·64	91	L. 8·4	1·0			
	14.	8	564·12	91	L. 8·4	2·0			
	14.	8	564·40	90	L. 8·4	2·0	563·3		5·496
	14.	8	564·28	90	L. 8·4	1·5			
	14.	9	522·88	85	L. 8·4	2·5	522·4	5·509	
	14.	9	523·32	84	L. 8·4	2·8			
	15.	11	562·92	84	L. 8·4	1·6			
	15.	11	563·34	88	L. 8·4	1·5	562·1	5·511	
	15.	11	562·80	89	L. 8·4	1·0			
	15.	12	479·84	89	L. 8·4	2·0			
	15.	12	479·96	92	L. 8·4	1·0	479·4	5·496	
	15.	12	480·40	89	L. 8·4	1·5			
	15.	13	470·60	95	L. 8·4	1·5			
	15.	13	470·56	98	L. 8·4	2·0	469·1	5·480	
	15.	13	470·20	93	L. 8·4	2·0			
Magnetic Observatory, Cape of Good Hope.	April 18.	5	627·20	88	G. 11·6	5·5			
	18.	5	627·36	88	G. 11·6	5·5	624·3	4·561	
	18.	5	627·26	84	G. 11·6	5·5			
	18.	6	704·08	82	G. 11·6	5·0			
	18.	6	703·66	81	G. 11·6	5·0	700·9		
	19.	6	702·68	76	G. 11·6	5·5			
	19.	7	712·90	85	G. 11·6	1·5			
	19.	7	712·78	84	G. 11·6	1·5	712·0	4·569	
	19.	7	713·20	83	G. 11·6	2·0			
	19.	8	618·78	84	G. 11·6	2·0			
	19.	8	617·50	79	G. 11·6	2·0	617·4		4·569
	20.	8	618·42	76	G. 11·6	2·5			
	20.	9	573·80	74	G. 11·6	2·0			
	20.	9	574·00	65	G. 11·6	2·5	573·4	4·572	
	20.	9	573·64	67	G. 11·6	3·0			
	19.	11	616·94	84	G. 11·6	1·5	616·3	4·587	
	19.	11	617·36	85	G. 11·6	2·0			
	19.	12	526·60	87	G. 11·6	2·5	525·9	4·566	
	19.	12	527·12	86	G. 11·6	2·0			
	19.	13	515·80	86	G. 11·6	2·5	514·3	4·561	
	19.	13	514·98	86	G. 11·6	2·0			
Simon's Bay	22.	5	624·20	71	G. 11·6	4·5	623·6	4·571	
	22.	5	623·88	67	G. 11·6	5·0			4·571
	22.	6	700·76	72	G. 11·6	4·0	699·4	4·571	
	22.	6	699·14	72	G. 11·6	5·0			

TABLE. (Continued.)

Station.	1842.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.	
			s	°	s	°	s		
Sisters' Walk (Station of Captain Ross), Saint Helena.	May 9.	5	553·50	76	G. 11·4	6·0	552·2	5·831	
	9.	5	554·16	78	G. 11·4	7·0			5·827
	9.	6	621·32	79	G. 11·4	5·0	619·6	5·824	
	9.	6	622·16	79	G. 11·4	5·5			
Sandy Beach, Ascension.	17.	5	527·48	87	G. 10·4	5·5			
	17.	5	527·60	90	G. 10·4	5·5	524·8	6·456	
	17.	5	527·68	92	G. 10·4	5·5			
	17.	6	592·44	95	G. 10·4	5·0			
	17.	6	591·32	90	G. 10·4	5·5	587·2		
	17.	6	591·08	91	G. 10·4	5·0			
	17.	7	599·44	88	G. 10·4	1·5			
	17.	7	600·50	89	G. 10·4	1·0	599·3	6·480	
	17.	7	600·04	76	G. 10·4	2·0			
	17.	8	520·80	77	G. 10·4	2·5			
	17.	8	520·56	77	G. 10·4	3·0	520·0		
	17.	8	520·76	77	G. 10·4	3·0			6·457
	17.	9	482·28	78	G. 10·4	3·0			
	17.	9	482·56	78	G. 10·4	3·0	481·7	6·480	
	17.	9	482·36	78	G. 10·4	3·5			
	18.	11	521·04	84	G. 10·4	2·0			
	18.	11	520·64	85	G. 10·4	2·0	519·8	6·444	
	18.	11	520·68	87	G. 10·4	1·5			
	18.	12	444·20	89	G. 10·4	2·5			
	18.	12	443·72	92	G. 10·4	2·5	443·0	6·463	
	18.	12	444·12	95	G. 10·4	2·0			
	18.	13	435·04	96	G. 10·4	2·5			
	18.	13	435·04	96	G. 10·4	2·5	433·5	6·417	
	18.	13	434·78	96	G. 10·4	2·5			
Royal Military Repository, Woolwich.	October 12.	5	689·48	57	G. 0·3	3·0			
	12.	5	688·77	56	G. 0·3	3·0			
	12.	5	688·60	57	G. 0·3	3·5			
	Dec. 27.	5	689·88	59	G. 5·6	4·5	691·3		
	27.	5	688·84	59	G. 5·6	5·0			
	27.	5	690·20	60	G. 5·6	5·0			
	28.	5	688·52	28	G. 5·6	3·5			
	October 12.	6	774·36	58	G. 0·3	2·5			
	12.	6	773·48	55	G. 0·3	2·5			
	12.	6	773·94	55	G. 0·3	3·0			
	Dec. 27.	6	775·40	60	G. 5·6	3·0	778·1		
	27.	6	775·84	61	G. 5·6	3·5			
	27.	6	775·68	61	G. 5·6	4·0			
	28.	6	768·00	30	G. 5·6	3·0			
	October 13.	7	789·68	61	G. 0·3	1·0			
	13.	7	790·12	61	G. 0·3	0·5			
	13.	7	790·00	61	G. 0·3	1·0	789·1		
	Dec. 28.	7	786·98	59	G. 5·6	1·0			
	28.	7	787·52	60	G. 5·6	1·0			
	Oct. 13.	8	684·32	61	G. 0·3	0·5			
	13.	8	684·60	60	G. 0·3	0·5			
	13.	8	684·02	61	G. 0·3	0·5	686·1		
	Dec. 28.	8	684·50	32	G. 5·6	1·0			
	28.	8	687·24	59	G. 5·6	1·0			
	28.	8	687·78	59	G. 5·6	1·5			
	Oct. 13.	9	634·28	59	G. 0·3	1·0			
	13.	9	634·12	58	G. 0·3	1·0			
	13.	9	634·24	58	G. 0·3	1·0	635·7		
	Dec. 28.	9	634·08	33	G. 5·6	1·0			
	28.	9	637·28	55	G. 5·6	1·5			
	28.	9	637·02	58	G. 5·6	2·0		3·720	

TABLE. (Continued.)

Station.	1842.	Needle.	Time of vibration.	Thermometer.	Chronometer rate.	Final semi-arc.	Corrected time, 75° Fahr.	Horizontal Intensity.
			s	°	s	°	s	
Royal Military Repository, Woolwich.	Oct. 12.	11	674·20	53	G. 0·3	1·0		3·720
	13.	11	673·52	58	G. 0·3	0·5	674·9	
	13.	11	673·50	57	G. 0·3	0·5		
	Dec. 27.	11	686·64	59	G. 5·6	1·5		
	27.	11	686·00	59	G. 5·6	1·5	686·4	
	28.	11	682·08	28	G. 5·6	0·5		
	Oct. 13.	12	583·32	58	G. 0·3	0·5		
	13.	12	584·04	59	G. 0·3	0·5		
	13.	12	583·68	61	G. 0·3	0·5	584·0	
	Dec. 27.	12	582·36	59	G. 5·6	1·5		
	27.	12	582·84	60	G. 5·6	2·0		
	28.	12	584·14	28	G. 5·6	1·0		
	Oct. 13.	13	568·80	61	G. 0·3	0·5		
	13.	13	569·00	61	G. 0·3	0·5		
	13.	13	569·52	61	G. 0·3	1·0		
	Dec. 28.	13	566·32	41	G. 5·6	2·5	569·4	
	28.	13	566·98	42	G. 5·6	2·0		
	28.	13	568·20	30	G. 5·6	1·0		
	1843.							
Falmouth	Feb.	11	682·74	39	G. 3·3	1·5	684·8	
		11	682·54	39	G. 3·3	1·5		

TABLE II.

Observations of the Inclination.

Station.	Date.	Poles. Direct.	Poles. Reversed.	Inclination.		Remarks.
	1840.	° ′	° ′	° ′	° ′	
Rarotonga Island	May 14.	−35 30·0	−36 47·0		−36 08·5	
Vavao Island	22.	−34 30·5	−35 46·9	−35 08·7	−35 06·9	
	22.	−34 27·5	−35 42·7	−35 05·1		
Nukulau Island	30.	−35 27·8	−36 49·0	−36 08·8		
	30.	−35 31·7	−36 46·1	−36 08·9	−36 09·2	
	30.	−35 30·9	−36 47·8	−36 09·8		
Banga Island	June 15.	−35 51·5	−37 08·2		−36 29·9	
Tanna Island	22.	−39 22·9	−40 23·3		−39 53·1	
Port Carteret, New Ireland	July 7.	−20 13·5	−21 19·5	−20 46·5	−20 49·2	
	7.	−20 08·5	−21 35·4	−20 51·9		
Britannia Island.	27.	−21 26·5	−22 37·1		−22 01·8	
Jobie Island	August 8.	−17 30·0	−17 32·0	−17 31·0		
	8.	−17 25·5	−17 35·7	−17 30·6	−17 28·4	
	14.	−17 19 8	−17 36·7	−17 28·2		
	14.	−17 06·5	−17 40·9	−17 23·7		
Shell Rock, Jobie Island ..	14.	−18 04·0	−18 27·7		−18 15·8	
Amsterdam Island........	24.	−14 51·7	−15 26·6		−15 09·1	
Bouro Island	31.	−20 07·1	−20 39·8	−20 23·4		
	Sept. 1.	−18 36·4	−21 58·8	−20 17·6	−20 23·4	
	1	−20 03·0	−20 55·1	−20 29·1		
Amboyna Island	1.	−20 32·6	−21 22·1	−20 57·4		
	1.	−20 45·7	−22 29·1	−21 37·4	−21 09·8	
	1.	−19 24·4	−22 39·4	−21 01·9		
	1.	−19 09·1	−22 56·5	−21 02·6		

TABLE. (Continued.)

Station.	Date.	Poles. Direct.	Poles. Reversed.	Inclination.	Inclination. (mean)	Remarks.
	1840.	° ′	° ′	° ′	° ′	
Macassar Island	Sept. 26.	−23 18·4	−23 36·9	−23 27·6	−23 42·2	
	26.	−23 45·4	−23 54·7	−23 50·0		
	26.	−23 36·9	−24 03·2	−23 50·0		
	26.	−23 29·4	−23 51·9	−23 41·2		
Solombo Island	Oct. 4.	−21 21·8	−27 08·7	−24 15·2	−24 16·1	
	4.	−21 25·2	−27 08·7	−24 17·0		
Pulo Kumpal, Borneo	7.	−16 21·9	−23 00·6	−19 41·2	−19 48·8	
	7.	−16 11·9	−22 58·2	−19 35·0		
	7.	−17 17·5	−22 40·7	−19 59·1		
	7.	−17 21·0	−22 39·0	−20 00·0		
Singapore*	18.	− 8 47·5	−15 49·3		−12 18·4	
Manila	Dec. 1.	23 11·6	9 43·3		16 27·5	
Sampanchow Island	30.	34 07·1	26 20·6	30 13·9	30 25·8	
	30.	35 36·0	25 39·4	30 37·7		
	1841.					
Hong Kong Island	Feb. 12.	34 50·4	25 15·0		30 02·7	
Macao	April 9.	34 44·0	25 17·6		30 00·8	
Singapore	Dec. 7.	−11 42·8	−12 40·6	−12 11·7	−12 01·4	
	7.	−11 44·1	−12 10·5	−11 57·3		
	7.	−11 38·0	−12 17·2	−11 57·6		
	8.	−11 01·1	−12 43·5	−11 52·3		
	8.	− 9 22·2	−14 54·0	−12 08·1		
Malacca	20.	− 7 49·5	−14 14·2		−11 01·9	
Penang	30.	− 1 25·7	− 7 39·7	− 4 32·7	− 4 40·4	
	30.	− 1 25·5	− 8 10·9	− 4 48·2		
	1842.					
Malora Island	Jan. 10.	− 2 07·2	− 8 47·6	− 5 27·4	− 5 29·3	
	10.	− 2 15·4	− 8 47·0	− 5 31·2		
Acheen Island	11.	− 2 48·3	− 9 08·7		− 5 58·5	
Point de Galle	24.	− 4 45·7	−11 30·7	− 8 08·2	− 8 07·0	
	24.	− 4 40·5	−11 33·0	− 8 06·7		
Seychelles	Feb. 21.	−29 17·6	−34 41·6	−31 59·6	−32 02·9	
	21.	−29 13·5	−34 56·6	−32 05·0		
	21.	−29 08·1	−35 00·4	−32 04·2		
Majambo Bay	March 10.	−44 52·3	−51 15·7	−48 04·0	−48 18·9	
	10.	−45 43·5	−51 42·0	−48 42·7		
	10.	−45 27·0	−50 52·9	−48 09·9		
Cape of Good Hope	April 18.	−50 40·8	−56 41·0	−53 41·0	−53 20·0	
	18.	−50 50·2	−55 07·9	−52 59·1		
Simon's Bay	22.	−50 43·1	−55 19·9	−53 01·5	−53 04·0	
	22.	−50 46·0	−55 27·0	−53 06·5		
St. Helena	May 9.	−11 55·7	−22 06·4		−17 01·0	

* "At Singapore, in October 1840, a cat got into the room where the dip instrument was placed and threw it down, breaking the axle of the needle and the levelling screws of the dip circle. A new axle was fitted by a watchmaker, with which the observations were made at Manila and in the Canton River; and on my return to Singapore, in December 1841, I had the satisfaction to find that the results obtained with the needle were in accordance with those of the magnetic observatory at this island."—*Extract from Sir Edward Belcher's Memoranda.*

Table III.

General Table of Captain Sir Edward Belcher's Magnetic Determinations. The longitudes in this Table are east of Greenwich; the declinations west when positive, east when negative; the values of the horizontal intensity are expressed in the scale of absolute measure, in which the horizontal intensity at Woolwich is 3·72; and the total intensities in the usual arbitrary scale, in which the total intensity at Woolwich (as in London) is 1·372.

Station.	Date.	Latitude.	Longitude.	Declination.	Inclination.	Intensity.		Remarks.
						Horizontal.	Total.	
		° ′	° ′	° ′	° ′			
Port Etches	1837.	+60 21	213 19	−31 38	+76 02·9	3·15	1·728	
Kodiack	1839.	+57 20	207 09	−26 43	+72 42·9	3·635	1·617	
Sitka	1837.	+57 03	224 34	−27 42	+75 51·5			
Sitka	1839.	+57 03	224 38	−29 32	+75 49·1	3·207	1·730	
Baker's Bay	1839.	+46 17	235 58	−19 11	+69 26·9	4·394	1·654	
Fort Vancouver....	1839.	+45 37	237 24	−19 22	+69 22·2	4·475	1·682	
Port Bodega	1839.	+38 18	236 58	−15 20	+62 53·4	5·440	1·577	
San Francisco	1837.	+37 48	237 37	−15 20	+61 53·8			
San Francisco	1839.	+37 48	237 37	−15 20	+62 05·8	5·524	1·560	
Monterey	1839.	+36 36	238 07	−14 13	+61 03·6	5·666	1·547	
Sta Barbara	1839.	+34 24	240 19	−13 28	+58 54·1	5·925	1·516	
San Pedro	1839.	+33 43	241 45	−13 08	+58 21·4	5·913	1·490	
San Diego	1839.	+32 41	242 47	−12 21	+57 06·1	6·142	1·495	
San Quentin	1839.	+30 22	244 02	−12 06	+54 29·9	6·468	1·472	
San Bartholomew ..	1839.	+27 40	245 07	−10 46	+51 41·0	6·780	1·445	
Magdalena Bay....	1839.	+24 38	247 53	− 9 15	+46 34·0	7·160	1·376	
Mazatlan	1839.	+23 11	253 36	− 9 24	+46 38·5	7·214	1·388	
San Lucas Bay	1839.	+22 52	250 07	− 8 38	+45 39·3	7·259	1·372	
San Blas..........	1837.	+21 32	254 44	− 8 34	+45 24·3	....	......	Palm Island
San Blas..........	1839.	+21 32	254 44	− 9 00	+44 32·5	7·421	1·376	Beach.
Oahu Island	1837.	+21 17	202 00	−10 39	+41 35·1			
Oahu Island	1839.	+21 17	202 00	....	+41 16·8	6·506	1·144	
Socorro Island	1839.	+18 43	249 06	− 6 56	+40 43·7	7·477	1·325	
Clarion Island	1839.	+18 21	245 19	− 8 05	+37 03·0	7·597	1·238	
Acapulco	1838.	+16 50	260 05	− 8 13	+37 57·4	7·91	1·326	
Realejo	1838.	+12 28	272 52	− 7 53	+34 36·9			
Panama	1837.	+ 8 57	280 31	− 7 02	+31 51·9	7·743	1·205	
Magnetic Island....	1837.	+ 8 04	278 15	− 7 37	+31 11·9			
Sampanchow Island .	1841.	+22 43	113 40	− 0 22	+30 25·8	7·605	1·166	
Hong Kong	1841.	+22 16	114 08	− 0 37	+30 02·7	7·574	1·156	
Macao	1841.	+22 11	113 30	− 0 35	+30 00·8	7·592	1·159	
Cocos Island	1838.	+ 5 34	272 58	− 8 24	+23 33·2			
Cocos Island	1839.	+ 5 34	272 58	....	+22 55·7	7·924	1·137	
Manila	1840.	+14 36	120 58	− 0 18	+16 27·5	7·869	1·084	
Puna Island	1838.	− 2 47	280 05	− 8 56	+ 9 0·8	7·74	1·036	
Ascension	1842.	− 7 56	345 36	+19 16	....	6·457	0·853	
Penang	1841.	+ 5 25	100 19	− 1 30	− 4 40·4	7·982	1·058	
Malora Island	1842.	+ 5 41	95 24	− 2 22	− 5 29·3	7·863	1·041	
Acheen Island	1842.	+ 5 36	95 20	− 2 22	− 5 58·5	7·828	1·040	
Callao............	1838.	−12 04	282 52	−10 44	− 6 14·3	7·37	0·980	
Pt de Galle........	1842.	+ 6 02	80 15	− 0 41	− 8 07·0	7·756	1·035	
Malacca..........	1841.	+ 2 10	102 15	− 1 36	−11 01·9	7·939	1·069	
Singapore	1841.	+ 1 17	103 51	− 1 39	−12 01·4	7·950	1·074	
Martins Island	1840.	− 8 56	220 20	− 6 16	−14 06·0	7·594	1·024	
Amsterdam Island..	1840.	− 0 20	132 08	− 1 24	−15 09·1	8·012	1·097	
St. Helena........	1842.	−15 55	354 17	+22 11	−17 01·0	5·827	0·805	

Table. (Continued.)

Station.	Date.	Latitude.	Longitude.	Declination.	Inclination.	Intensity.		Remarks.
						Horizontal.	Total.	
Jobie Island	1840.	− 1 50	136 41	− 4 09	−17 28·4	8·056	1·116	
Shell Rock........	1840.	− 1 57	136 21	− 3 00	−18 15·8	8·066	1·123	
Pulo Kumpal......	1840.	− 2 44	110 07	− 0 39	−19 48·8	8·038	1·128	
Bouro Island	1840.	− 3 23	127 06	− 1 06	−20 23·4	8·093	1·141	
New Ireland	1840.	− 4 41	152 44	− 7 13	−20 49·2	8·039	1·136	
Amboyna Island ..	1840.	− 3 42	128 10	− 1 14	−21 09·8	8·144	1·154	
Britannia Island ..	1840.	− 3 19	143 29	− 4 55	−22 01·8	7·832	1·116	
Macassar Island....	1840.	− 5 08	119 23	− 0 29	−23 42·2	8·029	1·159	
Solombo Island	1840.	− 5 35	114 23	− 1 24	−24 16·1	8·003	1·160	
Bow Island........	1840.	−18 05	219 07	− 6 34	−30 16·0	7·425	1·123	
Tahiti	1840.	−17 29	210 30	− 6 30	−30 17·7	7·491	1·146	
Seychelles	1842.	− 4 36	55 31	+ 2 01	−32 02·9	6·632	1·034	
Vavao Island	1840.	−18 39	186 00	− 9 34	−35 06·9	7·706	1·245	
Rarotonga Island ..	1840.	−21 12	200 14	− 8 34	−36 08·5	7·315	1·197	
Nukulau Island	1840.	−18 10	178 31	−10 25	−36 09·2	7·708	1·262	
Banga Island......	1840.	−18 20	178 10	−10 21	−36 29·9	7·718	1·269	
Tanna Island......	1840.	−19 32	169 29	−11 37	−39 53·1	7·790	1·342	
Majambo Bay	1842.	−15 14	47 00	+12 10	−48 18·9	5·496	1·092	
Simon's Bay	1842.	−34 12	18 26	+29 08	−53 04·3	4·571	1·005	
Cape of Good Hope	1842.	−33 56	18 29	+29 13	−53 20	4·569	1·011	

Memorandum of the particular spot of observation at Sir Edward Belcher's Magnetic Stations.

Port Etches. On the slate beach abreast of the anchorage.

Kodiack. On the slate beach, in sight of Cape Greville.

Sitka. In 1837, in the Governor's house on the hill. In 1839, in the summer-house of the Governor's private dwelling.

Baker's Bay. At the landing-place.

Fort Vancouver. One set in a room in the fort, no iron being visible: one set in the garden of the fort.

Port Bodega. On a fine slaty beach, near the stream.

San Francisco. At Yerba Buena.

Monterey. At the back of the house at the landing-place, being the spot where Mr. David Douglas made his observations.

Santa Barbara. On the sand at the landing-place.

San Pedro. On a small island.

San Diego. On the tongue on the eastern side; a sandy flat.

San Quentin. On the sandy beach.

San Bartholomew. On observation bluff.

Magdalena Bay. At the observatory station.

Mazatlan. In a house belonging to Messrs. Hayn, Keyser, and Co.

Cape San Lucas. In the sandy bay: the surrounding rocks of large-grained granite.

San Blas. In 1837, on Palm Island; objectionable, the rocks being volcanic. In

1839, on the beach at the arsenal, in a line between the Custom-house and the outer rocky point: the sand is about twenty feet deep.

Oahu. In 1837, in a room used as an office by Mr. J. Coffin Jones. In 1838, in a house belonging to Mrs. Holmes; both well-known places.

Socorro Island. On the cliff.

Clarion Island. On the sandy bank above the beach.

Acapulco. Near Fort San Carlos, outside the gate.

Realejo. On the N.W. high cliff of Cardon Island; rocks basaltic.

Panama. Near the ruins of the convent of San Francisco.

Magnetic Island. A small islet.

Sampanchow Island. Near Chuenpee, on a beach composed of coarse quartz sand.

Hong Kong. Near the harbour, on granite rocks.

Macao. In the garden of the house belonging to Messrs. Leslie and Dent.

Cocos Island. At the landing-place. The observations in 1838 were made under unfavourable circumstances.

Manila. Two positions; one at the house of Mr. Strachan, which did not afford very satisfactory results: the second on the mole head; an entire failure, owing probably to iron clamps used to bind the masonry.

Puna Island. On various points of the island.

Ascension Island. On the N.W. sandy beach.

Penang. In the garden of the Admiralty-house.

Malora Island. Called Bouro Island by the natives: it is volcanic.

Acheen Island. On the sandy point about 100 yards north of the flag-staff.

Callao. On the Plaza de los Muertos.

Point de Galle. On Utrecht bastion, behind the magazine.

Malacca. Near the small saluting battery.

Singapore. In 1840, under a covered landing in front of the Recorder's house, being the position of the French expedition, the Astrolabe and Zélée. In 1841, at the Magnetic Observatory.

Martin's Island. In the sandy bay S.E. of Pilot's Hill.

Amsterdam Island. A coral islet; on the sand, at the landing-place.

Saint Helena. Position of the Erebus and Terror at Sisters' Walk.

Jobie Island. On a limestone islet, one mile from the main island.

Shell Rock. Volcanic rock; on a sandy tongue projecting from it.

Pulo Kumpal. At the landing-place on Rendezvous Island, clay-slate.

Bouro Island. Beach in front of the battery.

Port Carteret. The sandy landing-place on Cocoa-nut Island.

Amboyna. On the S.W. outer curtain; position changed three times.

Britannia Island. On coral sand at the landing-place, Victoria Bay.

Macassar Island. Position pointed out as that of the French expedition, the Astrolabe and Zélée.

Solombo Island. At the landing-place.

Bow Island. At five positions on the island.

Tahiti. The observations at Papeete were made in the yard of the house belonging to the queen's aunt. The partial results were exceedingly discordant. The house is on the beach. Those at Point Venus were made at the spot usually selected, viz. just clear of the extreme trees; spot marked by a stone sunk for the purpose. The United States' expedition observed about 100 yards more towards the trees near the canoe sheds.

Seychelles. Island of St. Mary, on a bluff head on the western side facing the town. Rocks granite.

Vavao Island. In the king's garden.

Rarotonga Island. At the landing-place, a coarse gravel flat composed of basaltic pebbles.

Nukulau Island. On the Coral Island.

Banga Island. On a coral islet at the extremity of the eastern reef.

Tanna Island. In front of the Missionary-house, at the west landing-place.

Majambo Bay. Sandy bay three miles south of Captain Owen's "north point."

Simon's Bay. Position of the Erebus and Terror.

Cape of Good Hope. Magnetic Observatory.

X. *Contributions to Terrestrial Magnetism.—No. V.*

By Lieut.-Colonel EDWARD SABINE, *R.A., F.R.S.*

Received June 14,—Read June 15, 1843.

§ 8. *Observations within the Antarctic Circle, made on Board Her Majesty's Ships Erebus and Terror, in the Summer of* 1840, 1841, *in the Expedition under the command of Captain* JAMES CLARK ROSS, *R.N.*

§ 9. *Observations between Kerguelen Island and Van Diemen Island, made on Board Her Majesty's Ship Erebus, July and August* 1840.

§ 8. *Observations within the Antarctic Circle in the Summer of* 1840, 1841.

IN the present number of these Contributions, I have the pleasure of laying before the Royal Society the magnetic observations made by Captain JAMES CLARK ROSS, and the Expedition under his command, in the first of the three voyages in which these researches have been prosecuted within the Antarctic Circle; and I gladly avail myself of the opportunity which the occasion affords, of congratulating the Society on the successful completion of the labours and on the approaching return, of an Expedition, in which the Fellows individually, and as a body, have taken so strong an interest. A large portion of the observations contained in this number were made in southern latitudes never before reached by man; and nearly the whole in a part of the globe extremely difficult of access, but containing within itself a field for researches peculiarly needed for completing and perfecting, in the words of HALLEY, "the abstruse theory of terrestrial magnetism."

In presenting to the Royal Society this portion of the results of an arduous enterprise, undertaken at their recommendation, it appears no improper departure from the usual tone of these communications, to allude very briefly to the causes which, under Providence, have conduced to its safe and successful issue;—to the admirable preparation and equipment of the vessels on the part of the Government,—to the high qualities of its Commander, manifested in conducting to its close, almost without an accident, and to the fullest accomplishment of its objects, a service of such duration and peculiar hazard,—and to the excellent spirit in which the Commander has been seconded by Captain CROZIER, and supported by the officers and seamen who have been their worthy associates.

Viewed merely as an expedition of discovery, its voyages must ever rank high in the annals of those maritime achievements of which our country is proud; but as a scientific expedition, which is its more proper character, as well as that in which the

Royal Society must regard it with the greatest satisfaction, its best praise will undoubtedly be found in the record of its performances; and I hasten therefore to enter on that portion of them which I am now enabled to present to the Society.

The peculiar feature in the magnetic survey of the portion of the southern hemisphere now under notice is, that it was conducted almost exclusively on board ship, the observations being subject to the disturbance occasioned by the ship's iron, in a part of the globe where the effect of this influence becomes excessive. The first consideration, therefore, must be to investigate the corrections which it is necessary to employ in compensation. The analysis of the effects produced by the iron of a vessel, and the theory of their corrections, have been given by the late M. Poisson, in a memoir read in 1838, and published in the Transactions of the Académie des Sciences, entitled "Mémoire sur les déviations de la Boussole produites par le fer des Vaisseaux." In cases in which the disturbance is due, partly to the magnetism induced by the earth's influence in the soft iron of the vessel, and partly to permanent magnetism acquired and retained by harder portions of her iron, the complexity of the source from whence the disturbance originates renders its correction very difficult. But in wood-built ships, when proper precautions are taken in regard to the place in the ship in which the instrument is used in observation, the disturbing influence is generally found to be that of induced magnetism alone: and in this case the correction may be obtained with tolerable facility*. The disturbance produced by the iron of the Erebus and Terror appearing to be of the latter class, I requested my friend Mr. Archibald Smith, Fellow of Trinity College, Cambridge, who in his academic course obtained the highest distinction conferred by the University, to draw out from M. Poisson's fundamental equations, applicable to induced magnetism, the most convenient and practical formulæ for computing the corrections of the three magnetic

* Since this communication was read to the Royal Society, Mr. Airy has favoured me with the following note:—"M. Poisson's deductions are founded on the assumption, that the phenomena of magnetism depend on the action of two fluids which attract each other, but which each repel other portions of fluid of the same kind: and that induction is caused by an alteration in the arrangement of these fluids among the particles of iron, produced by the attraction and repulsion of the earth's magnetic fluids. His fundamental equations in common language may be stated as follows:—

$$\left.\begin{matrix}\text{Horizontal force towards the}\\ \text{ship's head, as disturbed,}\end{matrix}\right\} = A' \times \left\{\begin{matrix}\text{Undisturbed horizontal}\\ \text{force to ship's head}\end{matrix}\right\} + C \times \text{undisturbed vertical force.}$$

$$\left.\begin{matrix}\text{Horizontal force towards the}\\ \text{ship's head, as disturbed,}\end{matrix}\right\} = E' \times \left\{\begin{matrix}\text{Undisturbed horizontal}\\ \text{force to ship's side}\end{matrix}\right\}$$

$$\text{Vertical force, as disturbed} \ldots = G \times \left\{\begin{matrix}\text{Undisturbed horizontal}\\ \text{force to ship's head}\end{matrix}\right\} + K' \times \text{undisturbed vertical force.}$$

"These equations are the same as those obtained by Mr. Airy in the Philosophical Transactions, 1839, the first and second being the same as the two equations in page 184, and the third being the same as the last of the group of three equations in page 181. Mr. Airy's expressions however imply that G is equal to C. The calculations in the sequel of this paper seem to show that in the Erebus G is greater than C. Mr. Airy's deductions are founded on the assumption that each particle of iron is converted, by the earth's magnetic action, into a magnet with its length parallel to the direction of terrestrial magnetism."

elements, for the use of nautical men, and of others who might be engaged in reducing magnetic observations made at sea. He has obligingly furnished me with the following memorandum :—

"At a given geographical position let φ represent the total magnetic intensity of the earth ; θ the dip, which is considered positive when the north end of the needle dips below the horizontal plane, negative when it inclines above it ; ζ the azimuth of the ship's head, or the angle between the principal section of the ship and the magnetic meridian, which is considered positive when the ship's head is to the west of the magnetic north, negative when to the east. Let φ', θ', ζ', be the values of the same elements shown by a needle whose centre is at a given place in the ship, when affected by the magnetism induced in the soft iron of the ship by the magnetism of the earth. M. Poisson has shown that if the dimensions of the needle are very small compared to its distance from the iron by which it is affected, the following equations are true ;

$$\varphi' \cos\theta' \cos\zeta' = \varphi\,[A' \cos\theta \cos\zeta + B \cos\theta \sin\zeta + C \sin\theta],$$
$$\varphi' \cos\theta' \sin\zeta' = \varphi\,[D \cos\theta \cos\zeta + E' \cos\theta \sin\zeta + F \sin\theta],$$
$$\varphi' \sin\theta' = \varphi\,[G \cos\theta \cos\zeta + H \cos\theta \sin\zeta + K' \sin\theta].$$

"In these equations, A', B, C, D, E', F, G, H, K' are constants which depend only on the distribution of the iron in the ship relatively to the position of the needle and the plane of the horizon, and which continue the same for every geographical position of the ship, while the distribution of the iron within the ship, and the inclination of the ship to the horizon, remain the same.

"If the centre of the needle is placed in the principal section of the ship, and the iron is symmetrically distributed on each side of that section, it will easily be seen that for values of ζ equal in magnitude and opposite in sign, the corresponding values of ζ' are equal in magnitude and opposite in sign, and the corresponding values of φ' and θ' are respectively equal in magnitude and the same in sign. These results necessarily imply that B, D, F and H are equal to zero. The equations in this case become

$$\varphi' \cos\theta' \cos\zeta' = \varphi\,[A' \cos\theta \cos\zeta + C \sin\theta],$$
$$\varphi' \cos\theta' \sin\zeta' = \varphi\,.\,E' \cos\theta \sin\zeta,$$
$$\varphi' \sin\theta' = \varphi\,[G \cos\theta \cos\zeta + K' \sin\theta].$$

"If we divide each term by $\varphi A'$ and put $\frac{C}{A'} = a$, $\frac{E'}{A'} = b$, $\frac{G}{A'} = c$, $\frac{K'}{A'} = d$,

$$\frac{\varphi'}{A'\varphi} \cos\theta' \cos\zeta' = \cos\theta \cos\zeta + a \sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

$$\frac{\varphi'}{A'\varphi} \cos\theta' \sin\zeta' = b \cos\theta \sin\zeta . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

$$\frac{\varphi'}{A'\varphi} \sin\theta' = c \cos\theta \cos\zeta + d \sin\theta . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.)$$

"From these equations are derived the following:—

$$\frac{\varphi'}{A'\varphi'}\cos\theta' = (\cos\zeta\cos\zeta' + b\sin\zeta\sin\zeta')\cos\theta + a\cos\zeta'\sin\theta, \quad . \quad . \quad . \quad (4.)$$

$$\cos\zeta\sin\zeta' + a\tan\theta\sin\zeta' = b\sin\zeta\cos\zeta'; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

and representing $\zeta - \zeta'$, or the deviation by δ,

$$\sin\delta = a\tan\theta\sin\zeta' + (1-b)\cos\zeta'\sin\zeta \quad . \quad . \quad . \quad . \quad . \quad (6.)$$

$$= \frac{2a}{1+b}\tan\theta\sin\zeta' + \frac{1-b}{1+b}\sin(\zeta+\zeta') \quad . \quad . \quad . \quad . \quad . \quad (7.)$$

$$\tan\zeta' = \frac{b\sin\zeta}{\cos\zeta + a\tan\theta}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8.)$$

$$c\cos\zeta + d\tan\theta = b\sin\zeta\operatorname{cosec}\zeta'\tan\theta' \quad . \quad . \quad . \quad . \quad . \quad . \quad (9.)$$

$$= (\cos\zeta + a\tan\theta)\sec\zeta'\tan\theta' \quad . \quad . \quad . \quad . \quad . \quad (10.)$$

$$= \sqrt{(\cos\zeta + a\tan\theta)^2 + b^2\sin^2\zeta}\,\tan\theta' \quad . \quad . \quad . \quad . \quad . \quad (11.)$$

$$\tan\theta' = \frac{c}{b}\cdot\left(\cos\zeta + \frac{d}{c}\tan\theta\right)\sin\zeta'\operatorname{cosec}\zeta \quad . \quad . \quad . \quad . \quad . \quad (12.)$$

$$= c\,\frac{\cos\zeta + \frac{d}{c}\tan\theta}{\cos\zeta + a\tan\theta}\cdot\cos\zeta' \quad . \quad . \quad . \quad . \quad . \quad . \quad (13.)$$

$$= c\cdot\frac{\cos\zeta + \frac{d}{c}\tan\theta}{\sqrt{(\cos\zeta + a\tan\theta)^2 + b^2\sin^2\zeta}}. \quad . \quad . \quad . \quad . \quad . \quad (14.)$$

"From these equations, and observations made at one geographical position with the ship's head on different azimuths, the constants a, b, c, d, A' may be determined, and the corrections of the affected elements at any other geographical position may be calculated.

"a and b may be determined from observed deviations of the compass needle by means of equation (5.). A table of the deviations on each affected or compass course, and of the true magnetic course for each affected or compass course, may then be calculated by equations (6.) or (7.). In these equations ζ, which is an unknown quantity, occurs in the second term on the right-hand side; but the term is so small that an approximate value of ζ may be used, and the error caused thereby neglected. This error is least in equation (7.), which is also the most convenient for calculation except on east and west courses.

"To find the compass course for each true magnetic course, it will generally be sufficient to apply the deviations corresponding to the nearest true magnetic courses contained in the Table last described; but if the deviations are large, it will be better to construct a separate table by means of equation (8.).

"c and d may be determined from the true dip and the affected dips observed on different courses by means of equation (11.), or more easily by means of (9.) and (10.); observing that the values of ζ employed should be not observed values, but tabular

values calculated in the manner described above. A table of the affected dip, and of the dip corrections on each course, may then be calculated from (14.), or more easily from (12.) and (13.); observing that (12.) must not be used when the ship's course is nearly north or south, and that (13.) must not be used when the ship's course is nearly east or west, and that the values of ζ should be tabular, not observed.

"The constants may also be determined from observations of the total intensity, by means of the first four equations, and tables for the correction of the observed intensities may be constructed by means of these equations. For this purpose, equation (3.) should be used when the dip is large, and the others when the dip is small.

"The values of a and b may be determined very readily, and probably with great accuracy, from observations of the horizontal intensity with the ship's head on the four principal compass courses. For if H_n, H_w, H_s, H_e represent the values so observed, then

$$a \tan \theta = \frac{H_n - H_s}{H_n + H_s}, \quad \ldots \ldots \ldots \quad (15.)$$

$$b = \frac{H_w + H_e}{2 \sqrt{H_w H_s}}. \quad \ldots \ldots \ldots \quad (16.)$$

"If observations are made at equal intervals of time with the ship's head successively on the N., W., S., E., and N. points, the values of a and b thus determined will be independent of any regular increase or diminution of the intensity. If n, w, s, e represent the number of vibrations in equal times, on the four principal courses, of the same horizontal needle, beginning to vibrate in the same arc, and corrected for temperature alone,

$$a \tan \theta = \frac{n^2 - s^2}{n^2 + s^2}, \quad \ldots \ldots \ldots \quad (17.)$$

$$b = \frac{w^2 + e^2}{2\, n\, s}. \quad \ldots \ldots \ldots \quad (18.)$$

"The true declination may be found independently of the dip and of the constant a, by means of observations of the true azimuth of the ship's head on two courses. Let ψ represent the declination, which is considered positive when the north end of the needle is to the west of the true north, ω the true azimuth of the ship's head, which is positive when the ship's head is to the west of the true north; so that $\zeta = \omega - \psi$. And let ω_1, ζ'_1 and ω_2, ζ'_2 represent the observed values of ω and ζ' on the two courses,

$$\tan\left(\psi - \frac{\omega_1 + \omega_2}{2}\right) = \frac{b \sin(\zeta'_1 + \zeta'_2)}{2 \sin \zeta'_1 \sin \zeta'_2 - b \sin(\zeta'_1 - \zeta'_2) \cot \frac{\omega_1 - \omega_2}{2}}.$$

"If the observations are made with the ship's head on exactly opposite courses, $\omega_1 - \omega_2 = 180°$; and we have

$$\tan(\omega_1 - \psi) = \frac{2 \sin \zeta'_1 \sin \zeta'_2}{b \sin(\zeta'_1 + \zeta'_2)};$$

if at equal azimuths on each side of the magnetic north,

$$\psi = \frac{\omega_1 + \omega_2}{2}.$$

"The formula fails if $\zeta'_1 + \zeta'_2 = 180°$, the denominator becoming zero; the true value of tan $\left(\psi - \frac{\omega_1 + \omega_2}{2}\right)$ in that case is

$$\frac{b}{\sin 2\,\zeta'_1 + b \cos 2\,\zeta'_1 \cot \frac{\omega_1 - \omega_2}{2}}.$$

Corrections for the Erebus.—We will seek in the first instance the values of the constants a and b, because they are those which can be obtained with the greatest degree of exactness, being derived from observations with the compass needle, which are made with greater precision than those with the inclination or intensity needles. Before the Expedition quitted England, a suitable position in the midship line was chosen for magnetic observations on board ship, and the effect of the ship's attraction on a standard compass placed in that spot, was ascertained by observations with the ship's head turned successively on each of the thirty-two principal points. This was done in September 1839 at Gillingham near Chatham, where θ, or the Inclination, was at that epoch 69° 05′*.

The observations in the Erebus gave results as follows :—

Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.
	° ′		° ′		° ′		° ′
N.	+0 06	W.	+4 19	S.	+0 28	E.	−3 42
N. by W.	+1 12	W. by S.	+4 40	S. by E.	−0 19	E. by N.	−4 53
N.N.W.	+2 01	W.S.W.	+4 03	S.S.E.	−0 48	E.N.E.	−3 46
N.W. by N.	+2 10	S.W. by W.	+3 24	S.E. by S.	−1 23	N.E. by E.	−3 18
N.W.	+3 03	S.W.	+2 45	S.E.	−1 53	N.E.	−2 59
N.W. by W.	+3 28	S.W. by S.	+2 08	S.E. by E.	−2 21	N.E. by N.	−2 16
W.N.W.	+3 51	S.S.W.	+1 34	E.S.E.	−2 50	N.N.E.	−1 39
W. by N.	+4 09	S. by W.	+0 52	E. by S.	−3 17	N. by E.	−0 49

We perceive by this Table that, allowance being made for slight irregularities in the observations, the masses of iron which acted on the compass needle of the Erebus in its standard position were distributed symmetrically, or very nearly so, on either side of the vertical plane, passing through the longitudinal midship section. We may therefore safely employ, in computing the corrections, the more simple formulæ which are applicable under this condition.

To obtain the constants a and b of these formulæ we may arrange equations on the several points, from the observations in the Table, of the form

$$\cos \zeta \sin \zeta' - b \sin \zeta \cos \zeta' = - a \tan \theta \sin \zeta'.$$

* Reports of the British Association, 1838.

N. by W.	$\cdot 1905$	$- \cdot 2115\,b$	$= -$	$0\cdot 510\,a$	
N.N.W.	$\cdot 3482$	$- \cdot 3834\,b$	$= -$	$1\cdot 001\,a$	
N.W. by N.	$\cdot 4481$	$- \cdot 4916\,b$	$= -$	$1\cdot 454\,a$	
N.W.	$\cdot 4727$	$- \cdot 5258\,b$	$= -$	$1\cdot 850\,a$	
N.W. by W.	$\cdot 4193$	$- \cdot 4798\,b$	$= -$	$2\cdot 175\,a$	
N.N.W.	$\cdot 2954$	$- \cdot 3626\,b$	$= -$	$2\cdot 417\,a$	
W. by N.	$\cdot 1212$	$- \cdot 1936\,b$	$= -$	$2\cdot 566\,a$	
	$+ 2\cdot 2954$	$- 2\cdot 6483\,b$	$= -$	$11\cdot 973\,a.$	(1.)
W. by S.	$- \cdot 2689$	$+ \cdot 1876\,b$	$= -$	$2\cdot 566\,a$	
W.S.W.	$- \cdot 4130$	$+ \cdot 3423\,b$	$= -$	$2\cdot 417\,a$	
S.W. by W.	$- \cdot 5021$	$+ \cdot 4427\,b$	$= -$	$2\cdot 175\,a$	
S.W.	$- \cdot 5233$	$+ \cdot 4754\,b$	$= -$	$1\cdot 850\,a$	
S.W. by S.	$- \cdot 4729$	$+ \cdot 4359\,b$	$= -$	$1\cdot 454\,a$	
S.S.W.	$- \cdot 3574$	$+ \cdot 3301\,b$	$= -$	$1\cdot 001\,a$	
S. by W.	$- \cdot 1919$	$+ \cdot 1768\,b$	$= -$	$0\cdot 510\,a$	
	$- 2\cdot 7295$	$+ 2\cdot 3908\,b$	$= -$	$11\cdot 973\,a.$	(2.)
S. by E.	$\cdot 1915$	$- \cdot 1860\,b$	$=$	$0\cdot 510\,a$	
S.S.E.	$\cdot 3563$	$- \cdot 3366\,b$	$=$	$1\cdot 001\,a$	
S.E. by S.	$\cdot 4693$	$- \cdot 4451\,b$	$=$	$1\cdot 454\,a$	
S.E.	$\cdot 5161$	$- \cdot 4832\,b$	$=$	$1\cdot 850\,a$	
S.E. by E.	$\cdot 4900$	$- \cdot 4489\,b$	$=$	$2\cdot 175\,a$	
E.S.E.	$\cdot 3953$	$- \cdot 3459\,b$	$=$	$2\cdot 417\,a$	
E. by S.	$\cdot 2462$	$- \cdot 1888\,b$	$=$	$2\cdot 566\,a$	
	$+ 2\cdot 6647$	$- 2\cdot 4345\,b$	$=$	$11\cdot 973\,a.$	(3.)
E. by N.	$- \cdot 1088$	$+ \cdot 1939\,b$	$=$	$2\cdot 566\,a$	
E.N.E.	$- \cdot 2967$	$+ \cdot 3625\,b$	$=$	$2\cdot 417\,a$	
N.E. by E.	$- \cdot 4214$	$+ \cdot 4789\,b$	$=$	$2\cdot 175\,a$	
N.E.	$- \cdot 4732$	$+ \cdot 5252\,b$	$=$	$1\cdot 850\,a$	
N.E. by N.	$- \cdot 4494$	$+ \cdot 4888\,b$	$=$	$1\cdot 454\,a$	
N.N.E.	$- \cdot 3492$	$+ \cdot 3780\,b$	$=$	$1\cdot 001\,a$	
N. by E.	$- \cdot 1908$	$+ \cdot 2050\,b$	$=$	$0\cdot 510\,a$	
	$- 2\cdot 2895$	$+ 2\cdot 6323\,b$	$=$	$11\cdot 973\,a.$	(4.)

From (1.) and (4.), changing the signs of (1.) and summing, we have

$$- 4\cdot 5849 + 5\cdot 2806\,b = + 23\cdot 946\,a. \quad (5.)$$

From (2.) and (3.), changing the signs of (3.) and summing, we have

$$- 5\cdot 3942 + 4\cdot 8253\,b = - 23\cdot 946\,a; \quad (6.)$$

whence $10\cdot 1059\,b = + 9\cdot 9791$; and $b = + \cdot 9875$;

From (5.) and (6.), changing the signs of (6.) and summing, we have

$$47{\cdot}892\,a = {\cdot}4553\,b + {\cdot}8093\,; \qquad a = + {\cdot}0263.$$

We have also the equations at east and west;

$$\begin{array}{ll} \text{East} \;\ldots\ldots & 2{\cdot}617\,a = + {\cdot}0645 \\ \text{West} \;\ldots\ldots & -2{\cdot}617\,a = - {\cdot}0753\,; \end{array}$$

whence

$$a = \frac{{\cdot}1398}{5{\cdot}234} = + {\cdot}0267\,;$$

or including the observations at east and west in the general sum, we have $a = + {\cdot}0264$.

After the arrival of the Expedition at Hobarton, and before it sailed to the Antarctic Circle, a similar series of observations was made in the Erebus, on the 29th October 1840, and again repeated on her return to Hobarton the following autumn, viz. on the 29th June 1841. The south end of the needle being now the one which dipped below the horizon (θ being $-\ 70^\circ\ 40'$), the deviation of the compass was found to take place in the contrary direction to that which had been observed at Gillingham, the disturbance being towards the *west* as the ship's head went round from north by east to south, and towards the *east* as her head passed from south through west to north.

The line of no deviation was not found to correspond accurately with the north and south points of the compass on either of the occasions at Hobarton, but in 1840 coincided more nearly with the north by west and south by east, and in 1841 with the north by east and south by west. We may perhaps ascribe with probability irregularities of this nature to slight modifications in the distribution of the iron at different periods, which we cannot but view as of not unlikely occurrence; for example, such as might be occasioned by the ship being secured at different times by the starboard or the larboard chain cable. In looking through the observations of the Erebus, it is evident that there was no systematic or constant deviation of the plane of the ship's attraction from that of her principal section; but that the points of no disturbance were sometimes a little on the one side, and sometimes a little on the other, of the north and south points. It appears, therefore, not improper to class these irregularities with those others of accidental occurrence which occasion small discordances in partial results, and are usually ranged under the general technical head of errors of observation.

If, further, we compare generally the deviations in 1840 with those of April 1841, the latter appear systematically rather the more considerable in amount. Viewed as a single fact, this circumstance might be regarded simply as indicating that some change had taken place in the interim in the arrangement and distribution of the ship's iron, and an easy and natural explanation might appear to be afforded. It is however one of several facts which have presented themselves in the course of a careful examination of the observations of the first two years of Captain Ross's expedition, which seem to point to the possibility of a somewhat different cause, viz. that when

a ship changes her magnetic latitude, the corresponding change in the magnetism of the ship, or more strictly in that portion of it which is derived from induction, follows, but does not always, or altogether, take place instantaneously. It would accord with this supposition, that the disturbance of the compass should be less in the Erebus on her first arrival at Hobarton in 1840, than on her return there in 1841, because in 1840 she had recently passed through the lowest magnetic latitudes, and in 1841 she came immediately from the highest. The observations in 1840 give a less value for $a \tan \theta$ than those of 1841, and taking the dip at Hobarton as the value of θ, to which the induced magnetism of the ship on both occasions should strictly correspond, we should have a less value for a in 1840 than in 1841; whereas if with the same dip we take a mean between the disturbances of the compass on the first arrival and on the return, by which we may be conceived to neutralize in a great measure the temporary influences which have been supposed, we find the value of a to be almost identical with the result of the former experiments at Gillingham. From this accordance in the value of the constant in dips which differ so greatly as from $+ 69°$ to $- 70°$, we should infer the probability,—first, that the local attraction of the Erebus was due to induced magnetism alone, the influence of any portions of iron which, in the strict sense of the term, were permanently magnetic, being insensible;—and secondly, that no material change affecting the standard compass had taken place in the distribution of her iron. These inferences are by no means inconsistent with the supposition above suggested, that some portions of her iron might be of a quality intermediate between that of perfectly soft iron which undergoes instantaneous change, and that of iron which acquires permanent magnetism, and that such portions should be liable, in regard to their magnetic condition, to be more or less in arrear of the ship's magnetic position. I abstain from entering further into this question at present, because a fitter opportunity of doing so will be afforded when the whole of the observations of the Expedition shall be collected, including those which have yet to be made at Rio de Janeiro on the return from the high latitudes of the south, and in England after passing through the low magnetic latitudes of the equatorial region. Should it prove that the induced magnetism of a ship due to any particular dip requires time for its full development, more or less according to the various quality of her iron, the corrections to be applied may possibly in some ships be considerably complicated thereby: fortunately in the Erebus the difference in the amount of the disturbance on the two occasions at Hobarton, which gave rise to this discussion, is not of any serious consequence; and we may employ without any material inconvenience for our present purpose the mean of the two series as applicable generally between their respective dates, for which interval we specially desire the corrections.

Ship's head by compass.	Disturbance towards the west.			Ship's head by compass.	Disturbance towards the west.		
	1840.	1841.	Mean.		1840.	1841.	Mean.
	° ′	° ′	° ′		° ′	° ′	° ′
N.	+1 10	−0 26	+0 22	S.	−0 49	+0 43	−0 03
N. by W.	+0 24	−1 14	−0 25	S. by E.	−0 01	+2 32	+1 15
N.N.W.	−0 40	−2 01	−1 20	S.S.E.	+0 38	+3 06	+1 52
N.W. by N.	−1 54	−2 34	−2 14	S.E. by S.	+1 12	+3 51	+2 32
N.W.	−2 10	−2 55	−2 32	S.E.	+1 35	+4 34	+3 04
N.W. by W.	−2 58	−3 13	−3 05	S.E. by E.	+2 35	+5 01	+3 48
W.N.W.	−3 18	−3 51	−3 35	E.S.E.	+3 17	+4 45	+4 01
W. by N.	−3 39	−4 32	−4 06	E. by S.	+3 12	+5 21	+4 17
W.	−4 15	−4 59	−4 37	E.	+3 38	+5 07	+4 22
W. by S.	−4 13	−4 56	−4 35	E. by N.	+3 54	+4 46	+4 20
W.S.W.	−4 27	−4 41	−4 34	E.N.E.	+3 30	+4 06	+3 48
S.W. by W.	−4 39	−4 19	−4 29	N.E. by E.	+3 21	+3 45	+3 33
S.W.	−4 06	−3 40	−3 53	N.E.	+3 12	+3 08	+3 10
S.W. by S.	−3 36	−2 50	−3 13	N.E. by N.	+2 50	+2 39	+2 45
S.S.W.	−2 30	−2 15	−2 22	N.N.E.	+2 26	+1 30	+1 58
S. by W.	−1 39	−0 19	−0 59	N. by E.	+2 19	+0 38	+1 28

Employing the same formula as before, and forming equations from the observations on the twenty-eight points, being all the points excepting the north, south, east and west, we obtain

$$10\cdot1036\, b = +\ 9\cdot9673$$
$$b = +\ \cdot9865\,;$$

and from the sum of the thirty equations, including those at east and west, we have

$$+\ 57\cdot89\, a = +\ 1\cdot0439 + \cdot537\, b,$$
$$a = \frac{1\cdot0439 + \cdot5297}{57\cdot89} = +\ \cdot0272.$$

On the passage from Hobarton to the Antarctic Circle, the Expedition stopped at Auckland Island for the purpose of observing on the term day of November 1840. The Erebus was not swung at this station, but with the value of θ observed on shore $-\ 73°\ 10'$, and the declination observed on board whilst at anchor, with the ship's head on the east and west points, and on the E.N.E. and W.N.W. points, we may obtain a satisfactory value for a. On the supposition of the symmetrical distribution of the iron on either side of the longitudinal midship section, the deviation occasioned by it should be the same in amount, but with opposite signs, at east and west, and also at E.N.E. and W.N.W.; the amount, however, being slightly different at east and west from that at E.N.E. and W.N.W.

From the observations at east and west we have

$$\psi' = -\ 12°\ 52' \text{ at east, and } \psi' = -\ 22°\ 55' \text{ at west;}$$
$$\psi = \frac{\psi' + \psi'}{2} = -\ 17°\ 53'\cdot5, \text{ and}$$
$$\delta = \pm\ 5°\ 01'\cdot5\,; \text{ whence } a = +\ \cdot0265.$$

From the observations at E.N.E. and W.N.W.,

$\psi' = -13° 36'$ at E.N.E., and $-22° 06'$ at W.N.W.;

$\psi = -17° 51'$; $\zeta' = 67° 30'$, and $\zeta = 63° 15'$; whence $a = \cdot 0261$.

The mean of the two pairs of observations gives $a = + \cdot 0263$.

Whilst within the Antarctic Circle only a single opportunity occurred of observing the inclination otherwise than on board, and thus of obtaining a from $a \tan \theta$ by having an assured value of θ. This was on the 8th of January 1841, in lat. $- 68° 30'$, long. $176° 35'$, where the inclination observed on the ice with a needle in which the observation was complete by the reversal of the poles, was found to be $- 83° 35'$. The declination was observed on board on the same afternoon and following morning, as nearly as could be in the same geographical position, with the ship's head on several points, from which we may select for a determination of a those nearest to the east and west points. We have then the following observations:—

1. At	W. $\frac{3}{4}$ N.	$\psi' = - 46° 02'$	4. At	E. $\frac{3}{4}$ N.	$\psi' = - 20° 51'$
2. At	W. by S.	$\psi' = - 46\ 32$	5. At	E. by S. $\frac{1}{2}$ S.	$\psi' = - 19\ 58$
3. At	W. by S. $\frac{1}{2}$ S.	$\psi' = - 47\ 17$	6. At	E. by S. $\frac{3}{4}$ S.	$\psi' = - 20\ 22$

$$\left.\begin{array}{l} \text{From 1. and 4. we have } \psi = \dfrac{\psi' + \psi'}{2} = - 33° 27'\cdot 5 \\[2ex] \text{From 3. and 5. we have } \psi = \dfrac{\psi' + \psi'}{2} = - 33\ 37\cdot 5 \end{array}\right\} \text{Mean } - 33° 32'\cdot 5.$$

Hence

$$\begin{array}{ll} \delta_1 = - 12° 29'\cdot 5 & \delta_4 = + 12° 41'\cdot 5 \\ \delta_2 = - 12\ 59\cdot 5 & \delta_5 = + 13\ 34\cdot 5 \\ \delta_3 = - 13\ 44\cdot 5 & \delta_6 = + 13\ 10\cdot 5\ ; \end{array}$$

and having thereby the values of ζ, as we have those of ζ' by observation, we obtain

$$\begin{array}{ll} a_1 = + \cdot 0249 & a_4 = + \cdot 0259 \\ a_2 = + \cdot 0274 & a_5 = + \cdot 0275 \\ a_3 = + \cdot 0274 & a_6 = + \cdot 0266 \\ \hline \text{Means} \ldots + \cdot 0266 & + \cdot 0267 \end{array}$$

The deviation of the compass observed on board the Erebus during the stay of the Expedition at Christmas Harbour, Kerguelen Island, in July 1840, when the ship's head was on the N.E., S.E., N.W., and S.W. points, and at the points on either side of those points, viz. N.E. by N., N.E. by E., S.E. by S., S.E. by E., &c., will furnish an additional determination of the value of b:

	δ.	ζ'.	ζ.
N.W. by N.	−2·12	33 45	31 33
N.W.	−2·07	45 00	42 53
N.W. by W.	−2·42	56 15	53 33
S.W. by W.	−3·52	123 45	119 53
S.W.	−3·28	135 00	131 32
S.W. by S.	−2·38	146 15	143 37
S.E. by S.	+2·45	213 45	216 30
S.E.	+3·16	225 00	228 16
S.E. by E.	+3·47	236 15	240 02
N.E. by E.	+2·08	303 45	305 53
N.E.	+2·05	315 00	317 05
N.E. by N.	+1·27	326 15	327 42

Employing these values of ζ' and ζ in the formula

$$\cos\zeta\sin\zeta' - b\cos\zeta'\sin\zeta + a\tan\theta\sin\zeta' = 0,$$

and eliminating $a\tan\theta\sin\zeta'$, we have

$$5{\cdot}7471\, b = 5{\cdot}6233\,; \qquad b = {\cdot}9785.$$

Collecting now in one view the values of a, we have as follows:—

1. From the observations at Gillingham near Chatham $a = +{\cdot}0264$
2. From the observations at Hobarton . . . . . . $a = +{\cdot}0272$
3. From the observations at Auckland Island . . . $a = +{\cdot}0263$
4. From the observations in lat. $-68° 30'$, long. $176° 35'$ $a = +{\cdot}0267$

Mean. . . . $+{\cdot}0267$

From this near accordance in the values of a, obtained in dips varying from $+69° 05'$ to $-83° 35'$, we are warranted in regarding the local attraction in the Erebus as due to induced magnetism; and in employing the formulæ derived from M. Poisson's fundamental equations, which are based on the hypothesis of induced magnetism only, in computing corrections for the observations made on board that ship.

For the value of b we have

From the observations at Gillingham . . . . . . $b = +{\cdot}9874$
From the observations at Hobarton . . . . . . $b = +{\cdot}9865$
From the observations at Kerguelen Island . . . $b = +{\cdot}9785$

Mean . . . $+{\cdot}9841$

With these values of a and b, a table of double entry was formed, having for arguments ζ' and θ; ζ' being the compass direction of the ship's head when an azimuth was observed, and θ the inclination taken from the chart formed from the observations of that element on board ship, corrected in the manner that will be shown hereafter; the corrections for the ship's local attraction in the general Table of Declinations observed in the Erebus have been taken from the Table thus formed.

In geographical positions, where the inclication made a very near approximation to $-90°$, and when azimuths observed on the same day at places sufficiently near to each other included observations on the east and west points, or on points but little removed from them, on which the corrections for the deviation might have the same, or nearly the same, value, but with opposite signs, the inclination with which the corrections have been computed has been derived from the azimuths themselves in preference to being taken from the chart. In such cases, and when a and b have been elsewhere satisfactorily determined for the ship, the amount of disturbance which her iron produces on the compass needle furnishes itself a measure of the inclination, exceeding in precision that of the dipping needle used on board. If the ship's magnetism should have already conformed to the terrestrial dip, the inclination corresponding to the disturbance of the compass is that belonging to the geographical position, and the ship herself, with merely her compass needle, would become in such rare situations an inclinometer of great delicacy. But if the change in the magnetism of the ship from that due to a former magnetic locality be not yet fully developed, the inclination thus furnished by the compass needle is on that account also preferable to that which might be taken from the chart, or to the dip observed with the dipping needle either on board or on shore, for the correction of other azimuths observed at the same time. Whenever the inclination used for the declination corrections has been thus derived, a notice is annexed in its proper place in the general table. It may be useful to give an example, and I select for that purpose the observations on the afternoon of the 16th February 1841, when, from the amount of the declination ($-112°$ or $-113°$), the Expedition had without doubt penetrated to the south of the latitude of the magnetic pole; the particular observations are as follow:—

Latitude.	Longitude.	Ship's head. ζ'.	Declination observed. ψ'.
° ′ −76 35	° ′ 166 17	E. by S. ½ S.	° ′ − 64 23
76 36	166 17	N.N.W ½ W.	−136 19
−76 36	166 17	W.N.W.	−150 04
−76 36	166 16	N.W. by N.	−138 24
−76 36	166 16	W.	−158 51
−76 36	166 16	W. by S. ½ S.	−156 58
−76 36	166 16	S.W. ¼ W.	−156 05
−76 36	166 17	S.W. by N.	−154 06
−76 36	166 17	S.W. ¼ S.	−142 54
−76 37	166 16	E.N.E.	− 67 01
−76 37	166 16	E. by S.	− 67 53
−76 37	166 16	E. by S.	− 66 32
−76 37	166 16	E.S.E.	− 73 45
−76 37	166 35	S.E. by E.	− 73 40

From the observations at W., and E. by S., we have the approximate values of $\psi = \frac{\psi' + \psi'}{2} = -113° \, 01'$; δ at W. $= -45° \, 50'$; $\tan \theta = \frac{\sin \delta}{\cdot 0267}$; whence $\theta = -87° \, 52'$.

With this approximate inclination we compute δ at E. by S. $= + 45° \; 04'$; and with this correction, and the same observations as before, we have more precisely

$$\psi = - 112° \; 38'; \; \delta \text{ at W.} = - 46° \; 13'; \text{ and } \theta = - 87° \; 53'.$$

Substituting this value of θ in the formula

$$\sin \delta = \frac{2a}{1+b} \tan \theta \sin \zeta' + \frac{1-b}{1+b} \sin (\zeta' + \zeta),$$

we have the corrections and the corrected declination as follows:—

E. by S. ½ S.	Correction − 46° 03′;	$\psi' = -$ 64° 23′;	$\psi = -$ 108° 26′
N.N.W. ½ W.	Correction + 19 46;	$\psi' = -$ 136 19;	$\psi = -$ 116 33
N.N.W.	Correction + 41 38;	$\psi' = -$ 150 04;	$\psi = -$ 108 26
N.W. by N.	Correction + 23 31;	$\psi' = -$ 138 24;	$\psi = -$ 114 53
W.	Correction + 46 13;	$\psi' = -$ 158 51;	$\psi = -$ 112 38
W. by S. ½ S.	Correction + 44 03;	$\psi' = -$ 156 58;	$\psi = -$ 112 55
S.W. ¼ W.	Correction + 33 04;	$\psi' = -$ 156 05;	$\psi = -$ 123 01
S.W. by W.	Correction + 37 32;	$\psi' = -$ 154 06;	$\psi = -$ 116 34
S.W. ¼ S.	Correction + 29 45;	$\psi' = -$ 142 54;	$\psi = -$ 113 09
E.N.E.	Correction − 41 38;	$\psi' = -$ 67 01;	$\psi = -$ 108 39
E. by S.	Correction − 45 19;	$\psi' = -$ 66 32;	$\psi = -$ 111 51
E. by S.	Correction − 45 19;	$\psi' = -$ 67 53;	$\psi = -$ 113 12
E.S.E.	Correction − 42 18;	$\psi' = -$ 73 45;	$\psi = -$ 116 03
S.E. by E.	Correction − 37 32;	$\psi' = -$ 73 40;	$\psi = -$ 111 12
		Mean . . .	− 113 23

On comparing the values of ψ thus obtained from the observations on the easterly points, with those on the westerly points, it is evident that the remaining differences in the individual results are not occasioned by faults in the corrections, but that they are actual differences in the observations of azimuth. In the extreme circumstances to which the Expedition had attained, when by reason of the great amount of dip, the terrestrial force acting on the compass needle, and directing it to one part of the horizon in preference to another, was reduced to $\frac{1}{27}$th part of the whole amount of the terrestrial magnetic force in the same locality, the degree of accordance which was still preserved assuredly surpasses expectation*. The result at S.W. ¼ W. is the only one which presents an excessive discordance; and after a careful examination of the whole of the observations which the general table contains, it must be regarded

* The compass used in the Erebus was the first of the new naval compasses made under the direction of a Committee appointed by the Admiralty "for the improvement of ships' compasses." The magnet was composed of several thin plates of clock-spring suitably arranged, giving very considerable magnetic force, with a suspension improved both in mode and materials. This compass appears to have answered remarkably well in the very trying circumstances in which it was employed. Captain Ross was himself the Chairman of the Committee, which gave its services gratuitously: the other members were Captain Beaufort, R.N., Mr. Christie, Major Jervis, Captain Edward Johnson, R.N., and Lieut.-Colonel Sabine.

as a case of very unusual observation error. Were we to omit this result, the mean would become $-112° 39'$. When the corrections for local attraction become so great, it is necessary to be very accurate in noting the direction of the ship's head at the same instant that the azimuth is observed, as at the points where the changes of δ for changes of ζ' are very great, an error of a degree in the direction of the ship's head will make nearly the same error in the correction; on such occasions therefore the result is liable to an additional source of observation error of serious magnitude.

We have seen that when the inclination is $-87° 53'$, the sum of the deviations at east and west amounted to $92° 26'$; with $10'$ increase in the dip, their joint amount would have become $126° 52'$. The scale which the compass needle presents for the deduction of the inclination is consequently a very large one, when the inclination is so great as that which we are now considering; and it continues to increase in magnitude, until the compass ceases altogether to indicate the direction of the horizontal component of the terrestrial force, and points unchangingly, under every alteration of the ship's head, to the direction of the general resultant of the ship.

The terrestrial dip observed with a dipping-needle on board on the 16th of February, and corrected for the ship's attraction, was $-88° 20'$; that corresponding to the magnetism of the ship was, as we have seen, $-87° 53'$, being a little in arrear, in a magnetic sense, of her then position.

For the constants c and d in the formula for the correction of the inclination, we have to take into account, in the first instance, a series of observations of the inclination with the ship's head successively on the sixteen principal points of the compass, made on board the Erebus at Hobarton in November 1840, before her departure for the Antarctic Circle, and a similar series made at the same place in June 1841 on her return from the south. The inclination observed on shore was $-70° 40'$.

Ship's head by compass.	Inclination observed. 1840.	1841.	Mean.	Ship's head by compass.	Inclination observed. 1840.	1841.	Mean.
	° ′	° ′	° ′		° ′	° ′	° ′
N.	−71 52	−71 59	−71 55·5	S.	−69 49	−69 19	−69 34
N.N.W.	−71 55	−72 00	−71 57·5	S.S.E.	−70 00	−69 41	−69 50·5
N.W.	−72 03	−71 45	−71 54·0	S.E.	−70 22	−70 04	−70 13
W.N.W.	−71 30	−71 24	−71 27	E.S.E.	−70 45	−70 33	−70 39
W.	−71 16	−70 55	−71 05·5	E.	−70 58	−71 08	−71 03
W.S.W.	−70 55	−70 30	−70 42·5	E.N.E.	−71 33	−71 32	−71 32·5
S.W.	−70 20	−69 56	−70 08	N.E.	−71 35	−71 57	−71 46
S.S.W.	−70 07	−69 44	−69 55·5	N.N.E.	−71 42	−71 56	−71 49

Employing for the observations between N.N.W. and S.S.W., and N.N.E. and S.S.E. the formula

$$c \cos \zeta + d \tan \theta = b \sin \zeta \operatorname{cosec} \zeta' \tan \theta',$$

and for the other points

$$c \cos \zeta + d \tan \theta = (\cos \zeta + a \tan \theta) \sec \zeta' \tan \theta',$$

and using the values of ζ computed by means of the constants a and b already determined, we have the following equations:—

N.	$+ 1{\cdot}0000\, c - 2{\cdot}850\, d = - 2{\cdot}830$	S.	$- 1{\cdot}0000\, c - 2{\cdot}850\, d = - 2{\cdot}888$
N.N.W.	$+ {\cdot}9327\, c - 2{\cdot}850\, d = - 2{\cdot}845$	S.S.E.	$- {\cdot}9110\, c - 2{\cdot}850\, d = - 2{\cdot}906$
N.W.	$+ {\cdot}7351\, c - 2{\cdot}850\, d = - 2{\cdot}868$	S.E.	$- {\cdot}6617\, c - 2{\cdot}850\, d = - 2{\cdot}902$
N.S.W.	$+ {\cdot}4418\, c - 2{\cdot}850\, d = - 2{\cdot}848$	E.S.E.	$- {\cdot}3139\, c - 2{\cdot}850\, d = - 2{\cdot}880$
W.	$+ {\cdot}0761\, c - 2{\cdot}850\, d = - 2{\cdot}864$	E.	$+ {\cdot}0761\, c - 2{\cdot}850\, d = - 2{\cdot}858$
W.S.W.	$- {\cdot}3139\, c - 2{\cdot}850\, d = - 2{\cdot}889$	E.N.E.	$+ {\cdot}4418\, c - 2{\cdot}850\, d = - 2{\cdot}862$
S.W.	$- {\cdot}6617\, c - 2{\cdot}850\, d = - 2{\cdot}922$	N.E.	$+ {\cdot}7351\, c - 2{\cdot}850\, d = - 2{\cdot}845$
S.S.W.	$- {\cdot}9110\, c - 2{\cdot}850\, d = - 2{\cdot}888$	N.N.E.	$+ {\cdot}9327\, c - 2{\cdot}850\, d = - 2{\cdot}822$

Summing these equations, c is eliminated, and $d = \frac{45{\cdot}917}{45{\cdot}604} = 1{\cdot}0069$; and changing the signs in the equations from W. to E.S.E. inclusive and summing, we have $c = \frac{+{\cdot}361}{9{\cdot}9924} = + {\cdot}0361$.

A similar series of observations made at Auckland Island on the passage from Hobarton to the Antarctic Circle, furnishes values of c and d differing but slightly from the preceding. The inclination observed on shore was $- 73° \; 10'$.

Ship's head by compass.	Inclination observed.	Ship's head by compass.	Inclination observed.
	° ′		° ′
N.	−74 24	S.	−72 00
N.N.W.	−74 34	S.S.W.	−72 17
N.N.E.	−74 09	S.S.E.	−72 05
N.W.	−74 16	S.W.	−72 36
N.E.	−74 13	S.E.	−72 38
W.N.W.	−74 08	W.S.W.	−73 09
E.N.E.	−73 43	E.S.E.	−73 02
W.	−73 32	E.	−73 26

Treating these observations in a similar manner to those at Van Diemen Island, we obtain

$$c = + {\cdot}045\,; \quad d = + 1{\cdot}0039.$$

Giving double weight to the observations at Hobarton, as representing a double series, we have $c = + {\cdot}039$; and $d = + 1{\cdot}006$.

With these values of the constants in the formulæ

$$\tan \theta' = \frac{c}{b} \left(\frac{d}{c} \tan \theta + \cos \zeta\right) \sin \zeta' \operatorname{cosec} \zeta, \text{ from N.E to S.E., and from N.W. to S.W.}$$

$$\tan \theta' = c \frac{\left(\frac{d}{c} \tan \theta + \cos \zeta\right) \cos \zeta'}{a \tan \theta + \cos \zeta} \text{ on other points,}$$

a table of double entry was formed for the corrections of the observations of in-

clination in the Erebus, having for arguments θ and ζ'; the corrections in the general Table of the inclination observations were thus obtained.

We may compute the value of the remaining constant A′ from the variations of the magnetic intensity observed on board the Erebus at Hobarton with Mr. Fox's intensity apparatus, with the ship's head on the sixteen principal points of the compass; two series of such observations were made, one in October 1840 with needle R. F. 4, the other in July 1841 with needle R. F. 5; expressing the value of the intensity on shore by $1{\cdot}82 = \phi$, the several values on board ship are shown in the following Table:—

Ship's head by compass.	Intensity.			
	October 1840.	July 1841.	Means.	
N.	1·792	1·806	1·799	$1{\cdot}799 \;= \phi'$
N.N.E.	1·787	1·803	1·795	$1{\cdot}835 \;= \phi'$
N.N.W.	1·807	1·818	1·812	
N.E.	1·789	1·813	1·801	$1{\cdot}805 \;= \phi'$
N.W.	1·803	1·816	1·809	
E.N.E.	1·816	1·821	1·818	$1{\cdot}8245 = \phi'$
W.N.W.	1·830	1·832	1·831	
E.	1·828	1·823	1·826	$1{\cdot}828 \;= \phi'$
W.	1·832	1·829	1·830	
E.S.E.	1·830	1·829	1·830	$1{\cdot}836 \;= \phi'$
W.S.W.	1·848	1·837	1·842	
S.E.	1·842	1·853	1·848	$1{\cdot}853 \;= \phi'$
S.W.	1·862	1·855	1·858	
S.S.E.	1·858	1·859	1·859	$1{\cdot}8595 = \phi'$
S.S.W.	1·863	1·857	1·860	
S.	1·864	1·864	1·864	$1{\cdot}864 \;= \phi'$

Employing the formula

$$\frac{\phi'}{A'\phi}\sin\theta' = c\cos\theta\cos\zeta + d\sin\theta$$

with the values of θ' and ζ computed by means of the constants a, b, c and d, already deduced, and with the observed values of ϕ, θ, and ϕ', we have A′ as follows:—

At	N.	$A' = 0{\cdot}997$
At	N.N.E. and N.N.W.	$A' = 0{\cdot}996$
At	N.E. and N.W.	$A' = 0{\cdot}998$
At	E.N.E. and W.N.W.	$A' = 0{\cdot}993$
At	E. and W.	$A' = 0{\cdot}998$
At	E.S.E. and W.S.W.	$A' = 1{\cdot}002$
At	S.E. and S.W.	$A' = 1{\cdot}000$
At	S.S.E. and S.S.W.	$A' = 1{\cdot}002$
At	S.	$A' = 1{\cdot}002$
	Mean. . . .	0·999

We obtain the same result if we employ the *observed* values of θ' instead of the

computed values; in this case the inclination and total intensity being both furnished at the several points by observation with Mr. Fox's apparatus, we have the ratios of the horizontal intensity $\frac{\phi' \cos \theta'}{\phi \cos \theta}$ on board as follows:—

$$\text{N.} = 0{\cdot}9262; \quad \left.\begin{matrix}\text{N.N.E.}\\ \text{N.N.W.}\end{matrix}\right\} = 0{\cdot}9308; \quad \left.\begin{matrix}\text{N.E.}\\ \text{N.W.}\end{matrix}\right\} = 0{\cdot}9340;$$

$$\left.\begin{matrix}\text{E.N.E.}\\ \text{W.N.W.}\end{matrix}\right\} = 0{\cdot}9608; \quad \left.\begin{matrix}\text{E.}\\ \text{W.}\end{matrix}\right\} = 0{\cdot}9838; \quad \text{S.} = 1{\cdot}0800;$$

$$\left.\begin{matrix}\text{S.S.E.}\\ \text{S.S.W.}\end{matrix}\right\} = 1{\cdot}0615; \quad \left.\begin{matrix}\text{S.E.}\\ \text{S.W.}\end{matrix}\right\} = 1{\cdot}0432; \quad \left.\begin{matrix}\text{E.S.E.}\\ \text{W.S.W.}\end{matrix}\right\} = 1{\cdot}0084;$$

From which by the formula

$$H = A' (\cos \zeta \cos \zeta' + b \sin \zeta \sin \zeta' + a \tan \theta \cos \zeta'),$$

we have

$$\begin{array}{lll}
\text{At N.} & A' = \frac{0{\cdot}9262}{0{\cdot}9239} = 1{\cdot}003 \\
\text{At N.N.E. and N.N.W.} & A' = \frac{0{\cdot}9308}{0{\cdot}9270} = 1{\cdot}004 \\
\text{At N.E. and N.W.} & A' = \frac{0{\cdot}9340}{0{\cdot}9374} = 0{\cdot}996 \\
\text{At E.N.E. and W.N.W.} & A' = \frac{0{\cdot}9608}{0{\cdot}9555} = 1{\cdot}006 \\
\text{At E. and W.} & A' = \frac{0{\cdot}9838}{0{\cdot}9917} = 0{\cdot}992 \\
\text{At E.S.E. and W.S.W.} & A' = \frac{1{\cdot}0084}{1{\cdot}0122} = 0{\cdot}996 \\
\text{At S.E. and S.W.} & A' = \frac{1{\cdot}0432}{1{\cdot}0433} = 0{\cdot}999 \\
\text{At S.S.E. and S.S.W.} & A' = \frac{1{\cdot}0615}{1{\cdot}0673} = 0{\cdot}994 \\
\text{At S.} & A' = \frac{1{\cdot}0800}{1{\cdot}0761} = 1{\cdot}004
\end{array}$$

$$A' = 0{\cdot}999 \text{ Mean.}$$

The correction for the ship's attraction in the general table of the intensities observed in the Erebus, have been computed with this value of A' used in the formula $A' c \left(\frac{d}{c} \tan \theta + \cos \zeta\right) \cos \theta \operatorname{cosec} \theta'$; θ being taken from the chart formed from the observations of the inclination, and θ' and ζ from the tables with the arguments θ and ζ'.

Deduction of the Constants in Her Majesty's Ship Terror.—For these we have, in the first place, the observations at Gillingham, in September 1839, as follows: $\theta = 69° 05'$.

Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.
N.	$+\overset{\circ}{0}\cdot11$	W.	$+\overset{\circ}{5}\cdot55$	S.	$-\overset{\circ}{0}\cdot8$	E.	$-\overset{\circ}{5}\cdot22$
N. by W.	+1·35	W. by S.	+5·17	S. by E.	−0·51	E. by N.	−5·50
N.N.W.	+2·31	W.S.W.	+4·39	S.S.E.	−1·42	E.N.E.	−5·22
N.W. by N.	+3·9	S.W. by W.	+3·50	S.E. by S.	−2·30	N.E. by E.	−4·27
N.W.	+3·58	S.W.	+3·8	S.E.	−3·9	N.E.	−3·37
N.W. by W.	+4·39	S.W. by S.	+2·24	S.E. by E.	−3·40	N.E. by N.	−2·37
W.N.W.	+5·8	S.S.W.	+1·38	E.S.E.	−4·34	N.N.E.	−1·40
W. by N.	+5·35	S. by W.	+0·55	E. by S.	−4·57	N. by E.	−0·33

We perceive by this Table that the masses of iron acting on the compass needle of the Terror were distributed, as in the Erebus, symmetrically, or very nearly so, on either side of the vertical plane passing through the longitudinal midship section. Using the formula

$$\cos \zeta \sin \zeta' - b \sin \zeta \cos \zeta' = a \tan \theta \sin \zeta',$$

and forming equations for the several points, we have from the sum of those from N. by W. to W. by N., and from N. by E. to E. by N.,

$$-4\cdot4516 + 5\cdot3295\, b = +23\cdot946\, a;$$

and for the sum of the equations on the points from S. by W. to W. by S., and from S. by E. to E. by S.,

$$-5\cdot5092 + 4\cdot7551\, b = -23\cdot946\, a,$$

whence we derive $b = +\cdot9877$, and $a = +\cdot0339$; or including the observations at east and west $a = \cdot0343$.

We have next to consider a similar series of observations made in the River Derwent, near Hobarton, in Van Diemen Island, on October 20th, 1840, soon after the first arrival of the Expedition at that station; they were as follows:—

Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.	Ship's head by compass.	Attraction towards the west.
N.	$+\overset{\circ}{0}\ \overset{\prime}{42}\cdot4$	W.	$-\overset{\circ}{4}\ \overset{\prime}{36}\cdot6$	S.	$-\overset{\circ}{0}\ \overset{\prime}{11}\cdot6$	E.	$+\overset{\circ}{4}\ \overset{\prime}{24}\cdot4$
N. by W.	−0 23·6	W. by S.	−4 44·6	S. by E.	+0 52·4	E. by N.	+4 11·4
N.N.W.	−1 20·6	W.S.W.	−4 52·6	S.S.E.	+1 56·4	E.N.E.	+4 07·4
N.W. by N.	−2 20·6	S.W. by W.	−5 22·6	S.E. by S.	+2 38·4	N.E. by E.	+3 27·4
N.W.	−3 25·6	S.W.	−4 23·6	S.E.	+3 29·4	N.E.	+3 02·4
N.W. by W.	−3 56·6	S.W. by S.	−3 31·6	S.E. by E.	+4 00·4	N.E. by N.	+2 37·4
W.N.W.	−4 01·6	S.S.W.	−2 03·6	E.S.E.	+4 43·4	N.N.E.	+2 11·4
W. by N.	−4 06·6	S. by W.	−1 37·6	E. by S.	+4 28·4	N. by E.	+1 26·4

In the Terror, as in the Erebus, the disturbance had changed its sign in passing from the northern to the southern hemisphere: the symmetrical distribution of the

iron on either side of the principal axis of the ship continued as at Gillingham, the observations showing only those very small differences in the exact points of no disturbance, which have been remarked in the Erebus, and which we may be content to view as accidental differences. From these observations, pursuing the usual course, we obtain $b = + \cdot 9873$, and $a = + \cdot 0292$. Here also, as in the case of the Erebus, the observations on the first arrival at Hobarton give a somewhat less value for $a \tan \theta$ than those at Gillingham. It is possible that a similar series of experiments may have been repeated in the Terror on the return to the same station in 1841, but no record of it has been received in England, and the observations of 1840 are expressly referred to, in a note appended to them, as furnishing the corrections for the declinations observed between the months of October 1840 and April 1841. I think it not improbable that if the ship were swung in 1841, the resulting value of $a \tan \theta$ will prove, as in the Erebus, to be somewhat greater than in 1840, and that the mean value of a at Hobarton will thereby come into a closer accord with its value at Gillingham.

The practical effect of so small a difference is however unimportant, and I have taken a in round numbers for the declinations under consideration $= + \cdot 030$, and $b = + \cdot 9875$, and have computed with these values the Tables from which the corrections for the Terror's declinations have been taken.

Part of the materials required for the correction of the observations of inclination and intensity, made in the Terror during the voyage under notice, not having yet reached England, the deduction of the constants c, d, and A' for that ship has been postponed.

Index Correction of Needle R. F. 4 *for the Observations of the Inclination in the Erebus.*—The observations of the inclination at sea on board the "Erebus," were made with Mr. Fox's apparatus for determining the magnetic inclination and intensity, and one needle, R. F. 4, was used throughout the observations which are now under consideration. The poles were not reversed; the circle was used with the face east only, and the needle with its marked side towards the observer. An index correction is therefore required for all the sea observations, and must be sought by comparing the inclination shown by the same circle and needle when observed with in the same manner on shore, at stations where the inclination was otherwise determined in an independent and complete manner, viz. by needles of which the poles were reversed, and the needle and circle used in the eight ordinary positions.

The determinations of this description made by the Expedition at the Magnetic Observatory at Van Diemen Island in 1840 and 1841, at Auckland Island in November and December 1840, at Campbell's Island in December 1840, and on the ice in lat. $-68° 28'$, long. $176° 32'$, on the 8th of January 1841,—furnishing the required comparison,—were as follows :—

Observations of the Inclination, with Needles whose Poles were reversed, made at the Magnetic Observatory in Van Diemen Island in 1840, 1841.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1840.	h m		° ′	° ′	
September 12.	11 00 A.M.	R G 1	α −70 32·1 β −70 42·1	−70 37·1	Needles belonging to H.M.S. Erebus.
14.	11 20 A.M.	R G 2	α −70 35·6 β −70 40·9	−70 38·2	
21.	11 30 A.M.	R 4	α −70 39·7 β −70 35·5	−70 37·6	
21.	1 30 P.M.	R 10	α −70 49·8 β −70 53·7	−70 51·7	
22.	11 20 A.M.	R 6	α −70 46·5 β −70 45·2	−70 45·8	
22.	2 00 P.M.	R 7	α −70 46·4 β −70 45·2	−70 45·8	
October 5.	11 00 A.M.	R 6	α −70 42·4 β −70 44·0	−70 43·2	
5.	2 00 P.M.	R 7	α −70 43·3 β −70 40·4	−70 42·0	
15.	2 00 P.M.	D 1	α −70 31·4 β −71 11·1	−70 51·2	Needles belonging to Sir JOHN FRANKLIN.
16.	11 00 A.M.	D 2	α −70 08·4 β −71 06·4	−70 37·4	
19.	10 20 A.M.	C 1	α −70 42·0 β −70 34·5	−70 38·3	Needles belonging to H.M.S. Terror.
19.	11 00 A.M.	C 2	α −70 34·3 β −70 41·2	−70 37·7	
1841.					
April 14.	11 20 A.M.	R 4	α −70 38·6 β −70 38·8	−70 38·7	Needles belonging to H.M.S. Erebus.
14.	2 00 P.M.	R 10	α −70 46·5 β −70 39·3	−70 42·9	
15.	10 50 A.M.	R 6	α −70 34·7 β −70 43·3	−70 39·0	
15.	3 30 P.M.	R 7	α −70 40·6 β −70 33·9	−70 37·2	
16.	1 30 P.M.	R G 1	α −70 34·4 β −70 38·2	−70 36·3	
17.	11 20 A.M.	R G 2	α −70 35·7 β −70 39·0	−70 37·3	
24.	11 00 A.M.	C 1	α −70 41·1 β −70 35·0	−70 38·0	Needles belonging to H.M.S. Terror.
24.	Noon.	C 1	α −70 49·3 β −70 37·0	−70 43·1	
24.	2 00 P.M.	C 2	α −70 36·9 β −70 31·9	−70 34·4	
30.	Noon.	C 1	α −70 31·2 β −70 41·7	−70 36·4	
30.	Noon.	C 2	α −70 33·0 β −70 46·0	−70 39·5	
May 10.	2 20 P.M.	R 4	α −70 46·6 β −70 39·1	−70 42·9	Needles belonging to H.M.S. Erebus.
10.	4 15 P.M.	R 10	α −70 53·9 β −70 34·0	−70 43·9	
11.	10 30 A.M.	R 4	α −70 46·2 β −70 38·6	−70 42·4	
18.	10 45 A.M.	R 4	α −70 45·4 β −70 36·3	−70 40·9	
18.	2 15 P.M.	R 10	α −70 47·1 β −70 33·1	−70 40·5	
June 21.	9 45 A.M.	R 10	α −70 45·8 β −70 35·1	−70 40·4	
21.	10 45 A.M.	R 4	α −70 45·1 β −70 36·5	−70 40·8	
				−70 40·7	General Mean.

Observations of the Inclination with Needles whose poles were reversed, made at the Magnetic Observatory at Auckland Island.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1840.	h m		° ′	° ′	
November 23.	10 20 A.M.	R 4	α −73 17·9 β −73 08·2	−73 13·1	Needles belonging to H.M.S. Erebus.
23.	1 00 P.M.	R 10	α −73 14·4 β −73 12·4	−73 13·4	
23.	2 40 P.M.	R 6	α −73 15·7 β −73 12·9	−73 14·3	
23.	3 30 P.M.	R 7	α −73 14·7 β −73 11·6	−73 13·2	
25.	11 00 A.M.	R G 1	α −73 06·6 β −73 17·0	−73 11·8	
25.	1 00 P.M.	R G 2	α −73 04·0 β −73 11·6	−73 07·8	
27.	3 00 P.M.	C 1	α −73 08·7 β −73 02·9	−73 05·8	H. M. S. Terror.
27.	4 00 P.M.	C 2	α −73 08·2 β −72 55·5	−73 01·8	
December 4.	1 40 P.M.	R G 1		−73 12·2	H. M. S. Erebus.
				−73 10·4	General Mean.

Observations of the Inclination with Needles whose poles were reversed, at Campbell Island.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1840.	h m		° ′	° ′	
December 15.	9 30 A.M.	C 1	α −73 55·7 β −73 48·4	−73 52·1	Needles belonging to H.M.S. Terror.
15.	10 30 A.M.	C 2	α −73 51·2 β −73 43·4	−73 47·3	
15.	10 30 A.M.	R 4	α −73 56·5 β −73 50·7	−73 50·6	Needles belonging to H.M.S. Erebus.
15.	11 00 A.M.	R 10	α −74 01·5 β −73 57·2	−73 59·4	
15.	Noon.	R 6	α −73 45·8 β −73 49·5	−73 47·7	
15.	1 00 P.M.	R 7	α −73 49·5 β −73 53·3	−73 51·4	
				−73 51·4	General Mean.

Inclination observed on Ice, in latitude − 68° 28′, longitude 176° 32′, with a Needle the poles of which were reversed.

Date.	Hour.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
1841.	h m		° ′	° ′	
January 8.	3 20 P.M.	R 4	α −83 35·3 β −83 35·8	−83 35·6	H. M. S. Erebus.

The inclinations observed at the four preceding stations with needle R. F. 4, with the face of the circle east, and the marked side of the needle facing the observer, were as follows :—

Van Diemen Island	− 71° 06′·5 ;	true inclination − 70° 40′·7 ;	index correction − 25′·8
Auckland Island . .	− 73 41·3 ;	true inclination − 73 10·4 ;	index correction − 30·9
Campbell Island . .	− 74 20·3 ;	true inclination 73 51·4 ;	index correction − 28·9
On ice, Jan. 8, 1841	− 84 02·9 ;	true inclination − 83 36·6 ;	index correction − 27·3
		Mean . . .	− 28·2

An index correction of − 28′ has therefore been applied in the general table to the mean of the observations on each day with needle R. F. 4, in order to give the true or correct inclination, as it would have been observed by a needle in which the complete process of observation had been gone through.

Elements of Calculation of the Intensity Observations.—Of the intensity observations made with Mr. Fox's apparatus on board the Erebus, during the period under consideration, a large proportion was of the angles of deflection produced by deflecting magnets. A spare needle belonging to the apparatus was used as a deflector, and was fitted into a cylindrical case having screws at both ends, so that the needle could be applied either as "deflector N" with its north pole opposite that division of the circle which the north pole of the dipping needle had previously indicated as the dip, —or as "deflector S" with its south pole similarly applied to the opposite division of the circle.

The deflectors belonging to the apparatus, being too weak to produce sufficient deflections when used separately, were employed only conjointly, and are designated as "deflectors N and S." The angles of deflection varied in different localities during the voyage in round numbers as follows: deflector S from 50° to 45°; deflector N from 48° to 43°; and N and S from 23° to 20°.

To obtain the equivalent weight to the deflecting force of the deflectors at these angles, we have comparative observations of the angles produced by the deflectors and by weights at Hobarton, Auckland, and Campbell Islands, on the ice on the 8th January in lat. − 68° 28′, long. 176° 32′, and on five different occasions on board ship when the weather and other circumstances were favourable, viz. on February 8th and 10th, March 22nd, April 1st and 6th. These were exclusive of an attempt on the 1st of February, which failed on account of the ship having too much motion.

Hobarton is necessarily the primary station of the whole series of observations made in this portion of the voyage, being the only station at which an independent determination of the intensity has been made. It is also very suitable for a base station, because we may expect that the absolute as well as relative intensity will be determined with great precision at the magnetic observatory established there, and will ultimately furnish a correction, should one be needed, for the provisional value which must for the present be employed.

Captain Ross commenced the experiments for measuring the absolute horizontal intensity at Hobarton, by obtaining five results with the large magnets of his observatory magnetometers on different days whilst the Expedition was refitting there. The details of these will be published with the other magnetometric observations of the voyage; the results, which have been computed by Lieutenant Goodenough of the Royal Artillery from the data received from Captain Ross, are as follows:—

October 13, 1840	4·491	Mean 4·573*.
May 3, 1841.	4·626	
May 21, 1841.	4·602	
June 5, 1841	4·579	
June 25, 1841	4·566	

The dip being $-70° 40'$ at Hobarton, and the approximate value of the absolute horizontal intensity at Woolwich 3·72† with the dip of 69° 03′, the corresponding value of the total intensity at Hobarton in the arbitrary scale (London = 1·372) is 1·821. The previous *relative* observations, collected in No. I. of these Contributions, had given 1·819 as the mean of three determinations, viz.

FitzRoy	1836	1·817	Mean 1·819.
Franklin and Sabine.	1837 1838	1·810	
Wickham.	1838	1·830	

The closeness in the accordance of the mean results by the two methods can only be viewed as accidental, because the probable error of the absolute determination, estimated from the differences in the partial results, is far greater than the difference of the two methods; but it fully warrants 1·82 being now taken as a provisional value of the total intensity at Hobarton, as the base station of the observations which form the subject of this number, regarding $1{\cdot}82 + e$ as the true value, and e as a small correction to be determined hereafter, applicable to the whole series.

The weights employed in deflecting the intensity needle were from half a grain to six grains. It was soon found that half a grain was too small to give satisfactory results, and observations with that weight were discontinued. I have not therefore taken the observations made with it into account, except at Hobarton, where they

* Since these pages were written I have received the results of twenty-two monthly determinations of the absolute horizontal intensity at the magnetic observatory at Hobarton (ten in 1841 and twelve in 1842) made and computed by Lieutenant Kay, R.N., and the naval officers under his direction. The mean in 1841 is 4·553, the partial results varying from 4·601 to 4·509; and the mean in 1842, 4·513, the partial results varying from 4·443 to 4·568. The discordance in the partial results of these observations is scarcely less than in those of Captain Ross: there is also a considerable disagreement in the means of the three series, which may not improbably be diminished when the particulars of the several observations shall have been carefully examined, though the partial results must still be expected to differ much more widely than could be desired. It is hoped that such differences will be reduced within much smaller limits by the use of the improved apparatus which has recently been supplied to the Hobarton as well as to the other colonial observatories.

† Philosophical Transactions, 1843, Art. X.

assist in computing the angles corresponding to the weights of 4, 5, and 6 grains, which were not commenced with so soon. The observations with the weights on the days above stated, when the weights and deflecting magnets were employed in comparison, are collected in one view and given in the subjoined Table, in which are also shown the angles of deflection produced by the deflecting magnets on the same occasions.

1840.	Latitude.	Longitude.	Weights.		Thermometer.	Intensity deduced.		Angles of deflection by		
			Grains.	Angles of deflection.				Deflector S.	Deflector N.	Deflectors N and S.
	° ′	° ′		° ′	°			° ′	° ′	° ′
Sept. 18.	Hobarton. −42 52	147 24	½	2 41·4	52		1·820	50 01	Not observed	Not observed.
			1	5 22·7						
			1½	8 14·6						
			2	10 49·6						
			3	16 15						
			4	22 06						
			5	28 03·5						
			6	34 21						
Nov. 24.	Auckland Island. −50 33	166 19	1	5 18·4	52	1·844	1·852	49 29	46 50·2	Not observed.
			1½	8 02·2		1·867				
			2	10 36·8		1·856				
			3	15 58·3		1·851				
Dec. 14.	Campbell Island. −52 44	169 10	2	10 12·1	52	1·930	1·927	49 20·5	46 10·5	Not observed.
			3	15 30·2		1·906				
15.			1	4 59·2		1·963		49 17	46 45·7	Not observed.
			2	10 12·6		1·929				
			3	15 30·2		1·906				
1841. Jan. 8.	On ice. −68 28	176 32	3	14 34·3	42	2·024	2·017	47 16	44 17	21 55
			6	30 38·7		2·015				
Feb. 8.	−77 47	187 18	2	9 15·6		2·124	2·053	47 03	44 23	22 03
			3	14 14·6	32	2·071				
			6	30 30·9		2·023				
Feb. 10.	−77 39	187 06	2	9 31		2·067		46 55·5	44 14	21 55·9
			3	14 37		2·019				
			6	30 34·7		2·019				
Mar. 22.	−63 09	139 28	2	9 39	34	2·040	2·041	46 54	44 22	22 00
			3	14 13		2·074				
			3	14 18·6		2·062				
			4	19 34·1		2·045				
			5	25 11·2		2·012				
April 1.	−58 13	135 18	2	9 26·2	40	2·086	2·037	46 55	44 41	22 30
			3	14 07·7		2·086				
			4	19 39·7		2·035				
			5	25 28·5		1·990				
			6	31 08·5		1·987				
April 6.	−43 41	146 03	1	5 14·2	58	1·870	1·885	50 01	46 40	23 17
			2	10 37·2		1·885				
			3	15 59·4		1·850				
			4	21 21		1·881				
			5	26 29·7		1·919				
			6	32 58·5		1·887				

With the angles of deflection at Hobarton produced by the weights ½, 1, 1½, 2 and 3 grains, we obtain the equivalent weight 8·15 grains to the angle $v = 50° 01'$ of deflector S at the same station; and thence the value of the constant $\frac{w}{\mathrm{I} \sin v} = 5·84$

in the formula for the equivalent weights to the force of the deflector observed elsewhere, viz.

$$w' = 5{\cdot}84\,\mathrm{I}' \sin v'.$$

From the values of w' thus obtained, the subjoined Table has been formed of w' for each $20'$ of v for deflector N and deflector S, in the manner described in No. III. of these Contributions*; and with these values of w' we have the intensities I′ relative to the force 1·820 at Hobarton computed by means of the formula

$$\mathrm{I}' = \frac{\mathrm{I}\sin v}{w} \cdot w' \operatorname{cosec} v' = {\cdot}171\, w' \operatorname{cosec} v'.$$

Deflector S.		Deflector N.	
v'.	w'.	v'.	w'.
° ′	gr.	° ′	gr.
50 0	8·15	47 20	7·90
49 40	8·23	47 00	7·95
49 20	8·30	46 40	8·00
49 00	8·37	46 20	8·06
48 40	8·44	46 00	8·11
48 20	8·51	45 40	8·16
48 00	8·56	45 20	2·21
47 40	8·61	45 00	8·25
47 20	8·65	44 40	8·30
47 00	8·70	44 20	8·33
46 20	8·65	44 00	8·37

The results with the original magnets of the apparatus used conjointly, and designated as "N and S," are much inferior in precision to those obtained with the spare intensity needle used as a deflector. The angles of deflection were much less, owing to the force of the magnets, even when used conjointly, being very much inferior to that of the spare needle. The observations are of course given in the Table with the others, but as their results present on the one hand no systematic difference from those with the stronger deflector, and on the other hand are of inferior value, by reason of the extent of their fluctuation,—and as they could only tend therefore to impair the individual accuracy of the results with the stronger deflector and with the weights,—they have been omitted in the means.

Comparison of the Intensities deduced by the Weights and by the Deflectors at the Stations at which both were employed.

Station.	Latitude.	Longitude.	Deflector S.	Deflector N.	Weights.
	° ′	° ′			
Auckland Island. .	−50 33	166 19	1·862	1·873	1·852
Campbell Island . .	−52 41	169 10	1·875	1·898	1·927
On ice.	−68 28	176 32	2·021	2·044	2·017
At sea.	−77 17	187 18	2·034	2·038	2·053
At sea.	−77 39	187 06	2·041	2·047	2·053
At sea.	−63 00	139 28	2·043	2·039	2·041
At sea.	−58 13	135 18	2·042	2·017	2·037
At sea.	−43 41	146 03	1·820	1·884	1·885

* Philosophical Transactions for 1842, Art. II.

General Remarks.—The Tables of the declination observations in the Erebus and Terror, and of the inclination and intensity observations in the Erebus, furnish a full opportunity, for those who may desire it, to examine how far the corrections computed in the manner which has been described fulfil their purpose.

The three charts which accompany this number of the "Contributions," exhibit to the eye the determinations contained in the Tables, arranged in their respective localities, by which their general harmony may be, in some measure, judged of. The faint lines, representing the principal curves of the magnetic elements, are drawn in approximate conformity with the observations, and are designed merely to assist the eye in taking a first general view of the results. When the determinations of the succeeding voyages shall have been laid down in a similar manner on a south polar chart, they will furnish the means of judging of the course of the magnetic curves more comprehensively and accurately, and of tracing them accordingly.

Rather more attention has been bestowed on the lines in the chart of the inclination than in the other two charts, because it has been used for the values of θ in the declination-corrections. Having had experience in drawing similar charts on former occasions, and particularly those of the Magnetic Survey of the British Islands, I have no hesitation in recognising with Captain Ross, that as great, and greater, discrepancies are to be looked for, and must frequently be experienced, in magnetic surveys conducted on land, than in those made at sea. The chart of the inclination which accompanies this paper, constructed from observations made at sea, and certainly not under the most favourable circumstances, except in the skill of the observers, exhibits by no means a greater measure of discrepancy than the magnetic chart of Scotland or of Ireland: and it may be further noticed, that the only results which have been excluded altogether from the chart, by reason of their excessive discordance as well with each other as with the general body of results, are some that were made on islands which presented themselves in the course of the voyage.

I cannot close this section without calling the attention of all who take interest in the results of these researches, to the invaluable aid for which magnetical science is indebted to Mr. Fox. Without his instrument and method, which render observations of inclination and intensity made at sea nearly or altogether equal to those which could be made on land or on ice, such were the difficulties of the navigation, and such the inaccessible though magnificent character of the coast that was discovered, that two of the three charts herewith presented, and especially that of the intensity, must have offered an appearance very different from that which they now exhibit.

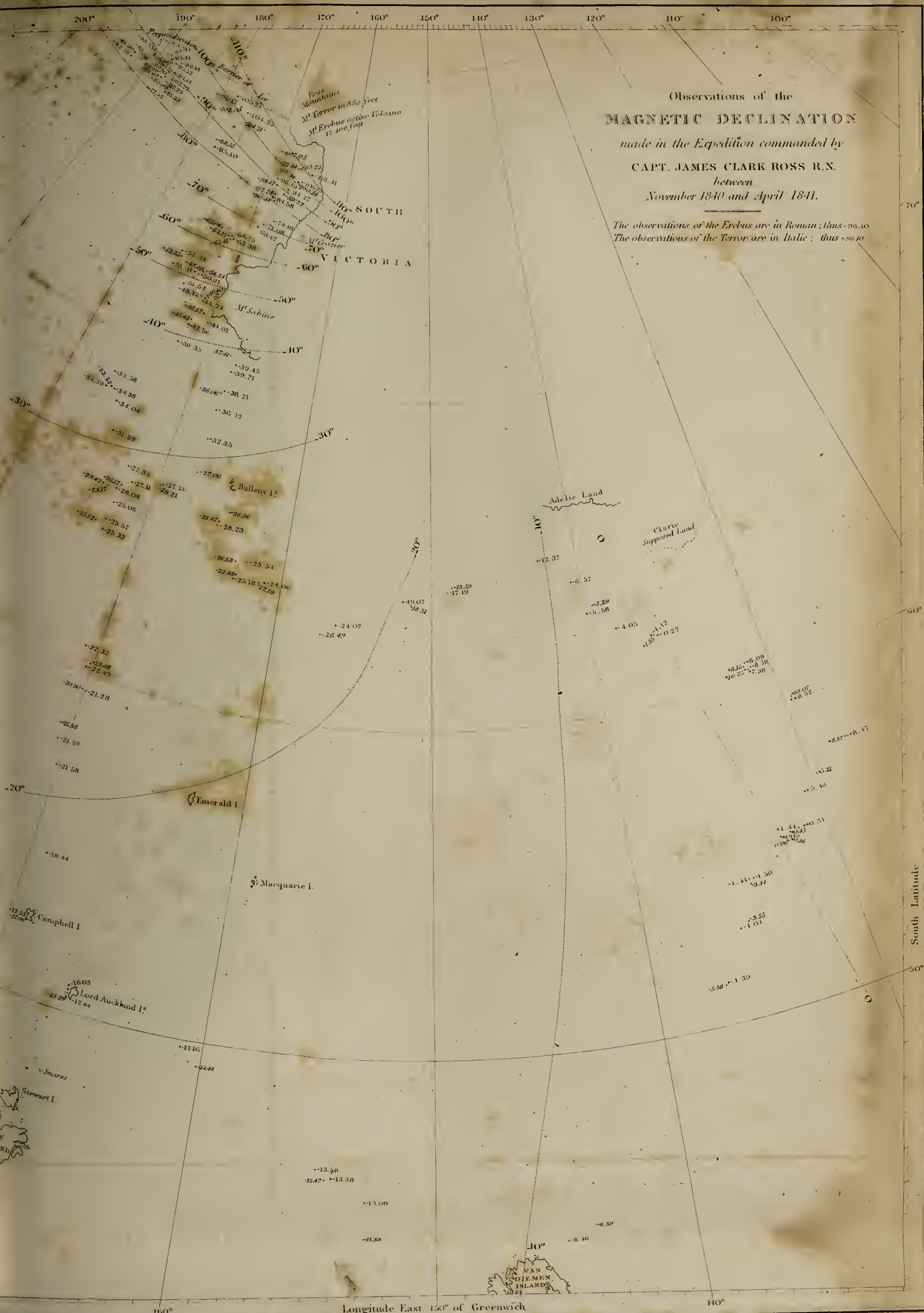
To enter into a lengthened comparison of the results now communicated with those of preceding observers, which have been embodied in magnetic maps constructed either directly from the phenomena, or by means of the mathematical theory of M. Gauss, would be to anticipate the more proper opportunity which will present itself, when the whole of the materials collected by the Antarctic Expedition shall be

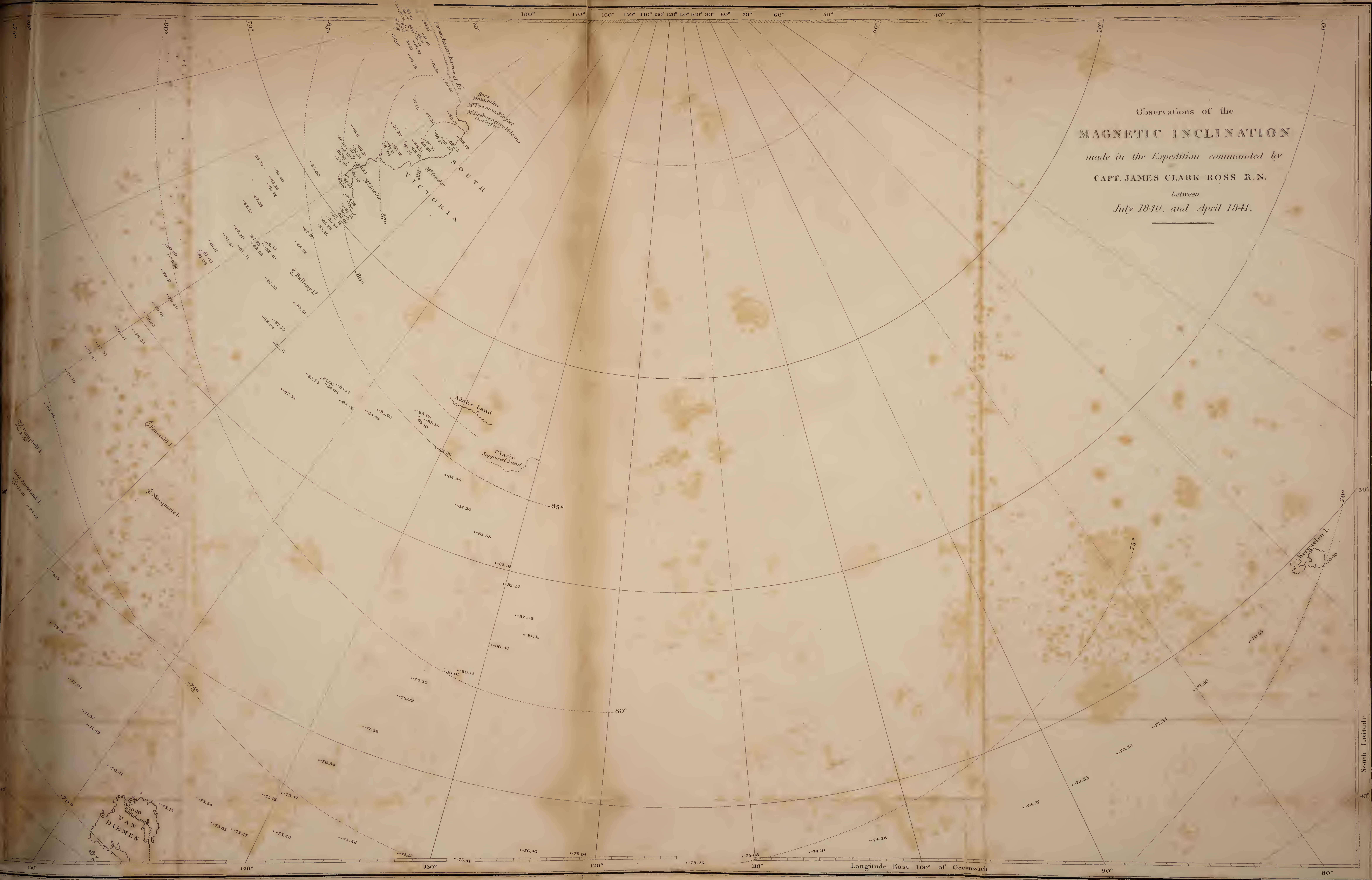
available for the comparison. A few remarks however on prominent points may be looked for on the present occasion.

1. The observations of declination, particularly those which point out the course of the lines of 0 and of 10° east, indicate a more westerly position than the one assigned by M. Gauss in the "Atlas des Erdmagnetismus" for the spot in which all the lines of declination unite. The progression of the lines in the southern hemisphere generally, from secular change, is from east to west; the difference consequently is in the direction in which a change should be found in comparing earlier with more recent determinations.

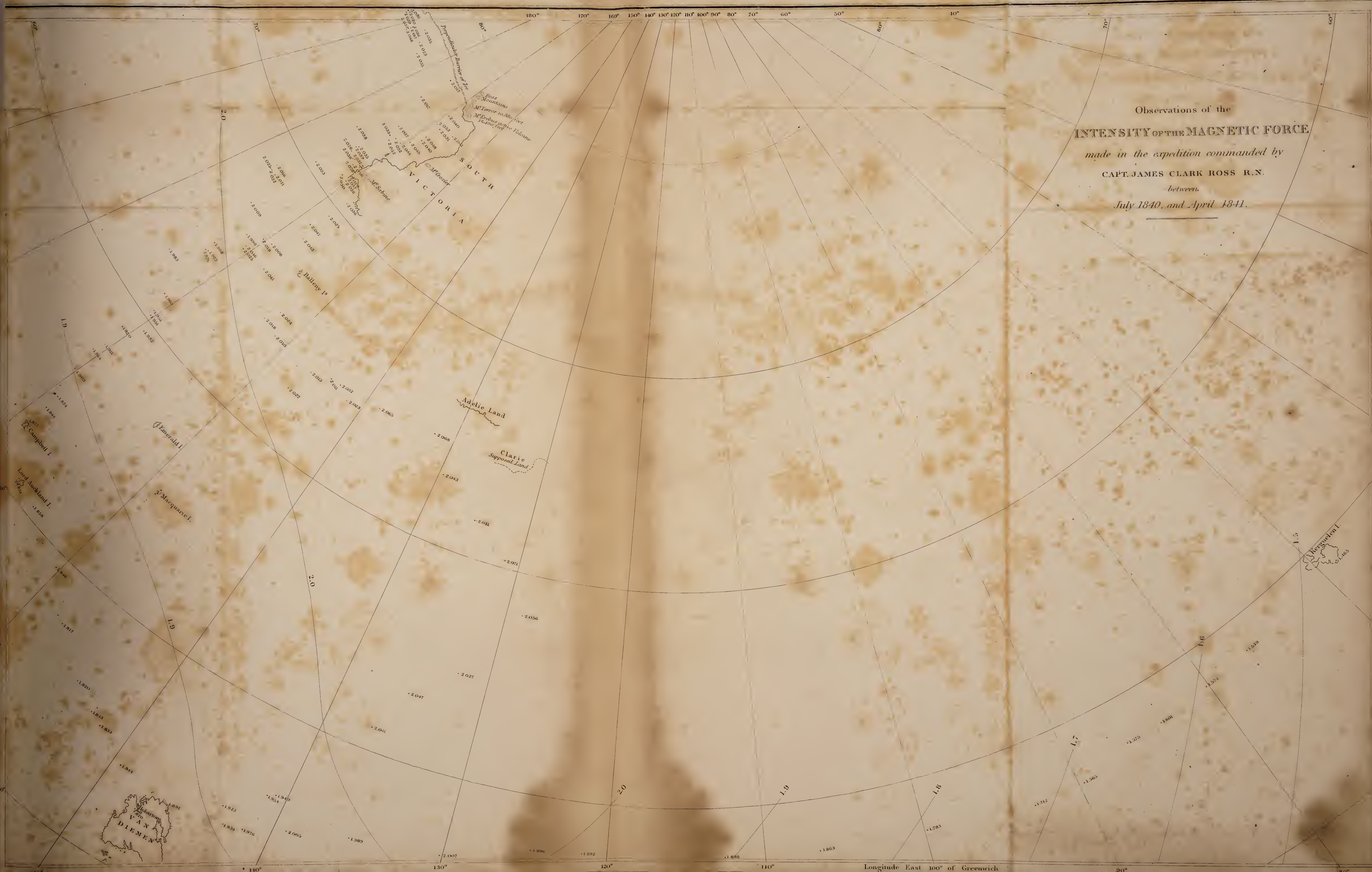
2. The general form of the curves of higher inclination in the southern hemisphere is much more analogous to that in the northern, than appears in M. Gauss's maps. For example, the isoclinal line of — 85° instead of being nearly circular, as represented in the 3te Abtheilung of Pl. XVI. of the "Atlas des Erdmagnetismus," is an elongated ellipse, much more nearly resembling in form and dimensions the ellipse of 85° of inclination in the northern hemisphere in the same work, Pl. XVI. 2te Abtheilung. The analogy between the two hemispheres in the characteristic feature of the elliptical form of the higher isoclinal lines is the more important to notice, on account of the particular relation which appears to subsist in the northern hemisphere, between the change in the geographical direction of the greater axis of the ellipse, and the secular changes of the inclination generally throughout the hemisphere. The present direction of the greater axis in the northern hemisphere is nearly N.N.W. and S.S.E., or that of a line passing through the two foci of maximum intensity. In the southern hemisphere the present direction of the greater axis differs little from E.S.E. and W.N.W.

3. Captain Ross's observations of the intensity do not appear to indicate the existence anywhere in the southern hemisphere of a higher intensity than would be expressed by 2·1 of the arbitrary scale. In this respect also the analogy between the two hemispheres appears to be closer than is shown in M. Gauss's maps, Atlas, Pl. XVIII. With respect to the direction of so much of the line of highest intensity (2·0) as it has been possible to draw with any degree of confidence from the observations now communicated, it will be found to be in almost exact parallelism with the isodynamic line of 1·7 in Plate III. of my memoir "On the Variations of the Magnetic Intensity" in the Reports of the British Association for 1838; which line was the highest of which the position could be assigned, for any considerable distance, by the aid of the then existing determinations.


Observations of the
MAGNETIC DECLINATION
made in the Expedition commanded by
CAPT. JAMES CLARK ROSS R.N.
between
November 1840 and April 1841.
The observations of the Erebus are in Roman; thus -96.10
The observations of the Terror are in Italic; thus -96.10
SOUTH
VICTORIA
Ross Mountains
Mt. Terror 10,880 feet
Mt. Erebus active Volcano 12,400 feet
Perpendicular Barrier of Ice
Mt. Sabine
Balleny Is.
Adelie Land
Clarie Supposed Land
Emerald I.
Macquarie I.
Campbell I.
Lord Auckland Is.
Snares
Stewart I.
VAN DIEMEN ISLAND
Longitude East 150° of Greenwich
South Latitude



J. & C. Walker Sculp.


Observations of the
INTENSITY OF THE MAGNETIC FORCE,
made in the expedition commanded by
CAPT. JAMES CLARK ROSS R.N.
between
July 1840, and April 1841.
Perpendicular Barrier of Ice
Ross Mountains
Mt. Terror 10,880 feet
Mt. Erebus active Volcano 12,400 feet
SOUTH VICTORIA
Mt. Sabine
Balleny Is.
Adelie Land
Clarie Supposed Land
Emerald I.
Campbell I.
Lord Auckland I.
Macquarie I.
Kerguelen I.
VAN DIEMEN
Hobarton
Longitude East of Greenwich
South Latitude

§ 9. *Observations of the Magnetic Inclination and Intensity made on board Her Majesty's ship Erebus on the passage from Kerguelen Island to Van Diemen Island in July and August* 1840.

These observations were made with Mr. Fox's apparatus, and with the same needle F which had been employed in the determinations made at sea on the passage from England to Kerguelen Island, discussed in § 5 and § 6 of these Contributions*. The inclinations at sea were observed with the face of the circle always to the east: the index correction for needle F in this position of the instrument has been derived by comparing similar observations made with it at the magnetic observatory at Kerguelen Island, with the results obtained at the same spot with other needles which had their poles reversed. These are contained in the following Table:—

Observations of the Inclication with needles whose poles were reversed, made at the Magnetic Observatory at Kerguelen Island, July 1840.

1840.	Hours.	Needle.	Poles. α direct. β reversed.	Mean.	Remarks.
	h m		° ′	° ′	
July 4.	10 A.M.	C 1	α—69 59·7 β—69 58·4	—69 59·0	Needles belonging to H. M. S. Terror. Observers, Captain Crozier, Lieut. Kay.
6.	6 P.M.	C 2	α—69 59·0 β—69 50·2	—69 54·6	
6.	6 15 P.M.	C 1	α—69 59·8 β—70 01·6	—70 00·7	
6.	6 30 P.M.	C 2	α—69 59·7 β—69 48·7	—69 54·2	
6.	7 20 P.M.	C 2	α—69 47·8 β—70 01·0	—69 54·4	
8.	1 45 P.M.	R 4	α—70 03·1 β—70 02·0	—70 02·5	Needles belonging to H. M. S. Erebus. Observer, Captain Ross.
9.	5 30 P.M.	R G 1	α—69 54·3 β—70 03·8	—69 59·1	
9.	7 30 P.M.	R G 2	α—69 57·7 β—70 04·0	—70 00·8	
10.	9 A.M.	R 10	α—70 13·9 β—70 08·9	—70 11·4	
				—69 59·6	General Mean.

The inclination observed with needle F at the same spot with the face of the circle towards the east was — 69° 57′·9; whence the index correction is — 1′·7.

The intensity of the magnetic force was determined in this portion of the voyage, on every day that the weather permitted, by the angles of deflection caused by a deflecting magnet. The observations were a continuation of the series of which the earlier portion is given in § 5 and § 6. The deflecting magnet employed was the deflector S. Tables are given, in the sections referred to, of the values of w' for this deflector corresponding to angles of deflection from 42° to 25°, derived from a comparison with the deflections produced by weights. The increase of the terrestrial force, in the passage between Kerguelen and Van Diemen Islands, brought the angle

* Philosophical Transactions, 1842, Art. II.

of deflection with deflector S down nearly to 20°. The weather was too unsettled to admit of any comparison being made with the weights at sea, and an accident which befel the needle on or before the arrival at Hobarton prevented the comparison which otherwise would have been made there. The values of w' corresponding to the angles of deflection from 25° to 20° have, therefore, been supplied, by continuing the rate of progression at which the deflecting force of the magnet S had been found by experiment, in angles from 36° to 25°, to increase as the angle diminished, viz. 0·033 gr. for each degree; we have thus the following values :—

$$v' = 26^\circ; \quad w' = 2{\cdot}594 \text{ gr.}$$
$$v' = 25; \quad w' = 2{\cdot}628$$
$$v' = 24; \quad w' = 2{\cdot}661$$
$$v' = 23; \quad w' = 2{\cdot}694$$
$$v' = 22; \quad w' = 2{\cdot}727$$
$$v' = 21; \quad w' = 2{\cdot}760$$
$$v' = 20; \quad w' = 2{\cdot}793.$$

At Kerguelen Island we have the angle of deflection with the magnet S = $26^\circ\ 21'{\cdot}3 = v$; the equivalent weight $= 2{\cdot}58 = w$; and (§ 6.) $\mathrm{I} = 1{\cdot}465$ (London $= 1{\cdot}372$); whence in other localities

$$\mathrm{I}' = \mathrm{I}\,\frac{w' \sin v}{w \sin v'} = {\cdot}2521\, w' \operatorname{cosec} v',$$

v' being furnished by the observation and w' taken from the preceding Table.

The last observation recorded to have been made with needle F was on the 11th of August, 1840, in lat. − 44° 16′, long. 142° 38′; when the angle of deflection being 21° 06′·5,

$\mathrm{I}' = 1{\cdot}929$ uncorrected for the ship's attraction, or (the course being E. by N. $\frac{1}{2}$ N.), $\mathrm{I}' = 1{\cdot}934$ corrected.

On the return of the Expedition from the Antarctic Circle in the following year, the ships regained their former track, and on the 5th of April, 1841, Captain Ross repeated the observations with different instruments within a few miles of the spot on which he had observed on the 11th of August, 1840: these observations gave $\mathrm{I}' = 1{\cdot}927$ in lat. − 45° 02′, long. 143° 10′. If we examine the map in which the intensity observations are inserted, we perceive that the direction of the two geographical positions in relation to each other is very nearly that of the isodynamic lines in that quarter; and if we refer generally to the Tables, we see that the difference in the resulting intensity on the two occasions is within the limits of the differences of partial determinations with the same instrument at one spot. As far as circumstances permit us to judge, therefore, we may view the observations of the two voyages as forming parts of one connected series.

As the ship's head during the run under consideration varied but little on any occasion from her direct course, and as that course is one on which the corrections, both of inclination and intensity, are small, I have taken them from the Table computed by means of the constants deduced in the preceding section.

Observations of the Inclination with Needle F on board H.M.S. Erebus, between July 22nd and August 11, 1840, on her passage from Christmas Harbour, Kerguelen Island, to Hobarton, Van Diemen Island.

1840.	Latitude.	Longitude.	Method employed.	Inclination. Face east.	Ship's head.	Corrections for ship's attraction.	Corrected inclination.	Remarks.
	° ′	° ′		° ′		′	° ′	
June 26.	Magnetic Observatory, Kerguelen Island.		Direct.	−70 02·8	Observed on shore.	....	−69 59·6	Remark by Captain Ross. "From these observations the Index error of Needle F. (face east), as used on board ship, may be obtained."
			S.	−69 56·3				
	−48 41	68 54	S. and N.	−69 48·3				
			N.	−70 04·2				
July 22.	−48 29	76 55	Direct.	−70 34·5	S.E. by E.	−18	−70 55	
22.			S.	−70 36				
23.	−48 17	80 15	Direct.	−71 48	S.E. by E. ½ E.	−12	−71 50	
23.			S.	−71 34·4				
24.	−47 55	83 51	Direct.	−72 10	S.E. by E. ½ E.	−13	−72 34	
24.			S.	−72 29				
25.	−47 46	86 18	Direct.	−73 4·5	S.E. by E. ½ E.	−15	−73 33	
25.			S.	−73 28·5				
26.	−47 12	89 45	Direct.	−73 13	S.E. by E. ½ E.	−15	−73 35	Considerable swell.
26.			S.	−73 24·5				
27.	−47 03	93 0	Direct.	−74 11·3	S.E. by E. ½ E.	−16	−74 37	A high sea.
27.			S.	−74 27·5				
28.	−47 13	97 07	Direct.	−73 14·5	S.E. by E. ½ E.	......	....	Too much motion to continue.
30.	−47 39	102 42	Direct.	−74 15	E.S.E.	− 8	−74 28	
30.			S.	−74 22·5				
31.	−47 35	106 26	Direct.	−74 15·2	E.S.E.	− 8	−74 31	
31.			S.	−74 26·4				
Aug. 1.	−47 45	110 39	Direct.	−74 48	E.S.E.	− 9	−75 08	Much motion.
1.			S.	−75 6				
2.	−47 34	114 15	Direct.	−75 20·5	E. by S. ½ S.	− 1	−75 26	
2.			S.	−75 6				
4.	−47 41	121 30	Direct.	−76 9·8	E. by S.	+ 6	−76 04	Much motion.
4.			S.	−76 6·3				
5.	−47 34	124 43	Direct.	−76 49·2	E. ½ S.	+13	−76 40	Very unsteady.
5.			S.	−76 53·7				
6.	−46 44	128 26	Direct.	−76 1·6	E.	+21	−75 41	
6.			S.	−75 59				
7.	−46 13	132 0	Direct.	−75 43·7	E. ½ N.	+29	−75 17	
7.			S.	−75 45				
8.	−45 59	135 38	Direct.	−74 33·5	E. by N.	+36	−73 48	
8.			S.	−74 11				
9.	−45 17	139 19	Direct.	−74 17·5	E.N.E.	+48	−73 23	
9.			S.	−74 0·4				
10.	−44 24	141 39	Direct.	−73 39·15	N.E. by E.	+59	−72 37	
10.			S.	−73 33				
11.	−44 16	142 38	Direct.	−73 37·15	E. by N. ½ N.	+42	−73 03	
11.			S.	−73 49				

The index correction − 1′·7 has been applied in the final column.

Observations of the Magnetic Intensity with Needle F, on board H.M.S. Erebus, between July 22nd and August 11th, 1840, in her passage from Christmas Harbour, Kerguelen Island, to Hobarton, Van Diemen Island.

1840.	Latitude.	Longitude.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections for ship's attraction.	Corrected intensity. London=1·372.	Remarks.
June 26 and 28.	On shore at Kerguelen Island.		W. 1½ gr.	14° 48′·6	34·5	Observed on shore.	1·465	....	1·465	At the Magnetic Observatory.
			W. 2 grs.	20 19·6	34·5					
	−48° 41′	68° 54′	S.	26 21·3	34·5					
July 22.	−48 29	76 55	S.	25 0·3	34	S.E. by E.	1·563	−·024	1·539	
23.	−48 17	80 15	S.	24 39·4	33	S.E. by E. ½ E.	1·594	−·020	1·574	
24.	−47 55	83 51	S.	24 20	39	S.E. by E. ½ E.	1·621	−·020	1·601	
25.	−47 46	86 18	S.	24 38·5	35	S.E. by E. ½ E.	1·595	−·020	1·575	
26.	−47 12	89 45	S.	24 46·5	34	S.E. by E. ½ E.	1·585	−·020	1·565	Considerable swell.
27.	−47 03	93 0	S.	23 04	44	S.E. by E. ½ E.	1·732	−·020	1·712	A high sea.
28.	−47 13	97 07	S.	23 04	44	S.E. by E. ½ E.	1·732	−·020	1·712	Much motion.
30.	−47 39	102 42	S.	21 37·5	43	E.S.E.	1·872	−·017	1·855	
31.	−47 35	106 26	S.	21 33·6	44	E.S.E.	1·880	−·017	1·863	
Aug. 1.	−47 45	110 39	S.	22 01·7	35	E.S.E.	1·832	−·017	1·815	Much motion.
2.	−47 34	114 15	S.	20 37	42	E. by S. ½ S.	1·984	−·014	1·970	
4.	−47 41	121 30	S.	20 27·7	40	E. by S.	2·002	−·010	1·992	Very unsteady.
5.	−47 34	124 43	S.	20 28·2	41	E. ½ S.	2·002	−·006	1·996	Very unsteady.
6.	−46 44	128 26	S.	20 10·5	42	E.	2·037	−·003	2·034	
7.	−46 13	132 0	S.	20 39·2	49	E. ½ N.	1·980	0	1·980	
8.	−45 59	135 38	S.	20 34·7	51	E. by N.	1·987	+·002	1·989	
9.	−45 17	139 19	S.	20 31·1	55	E.N.E.	1·997	+·008	2·005	
10.	−44 24	141 39	S.	20 48·7	50	N.E. by E.	1·962	+·014	1·976	
11.	−44 16	142 38	S.	21 06·5	48	E. by N. ½ N.	1·929	+·005	1·934	

Declinations observed on board Her Majesty's Ship Erebus between November 15, 1840, and April 6, 1841.

The Observers are distinguished in the column of Initials as follows:—R. Captain Ross; S. Lieut. Sibbald; W. Lieut. Wood; T. Mr. Tucker, Master; Sm. Mr. Smith, and O. Mr. Oakley, Mates; Y. Mr. Yule, Second Master. East Declination is characterised by the sign —.

1840.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′			° ′	° ′	° ′	
Nov. 15. P.M.	−45 33	152 49	R.	− 8 55	E.S.E.		− 4 39	−13 34		
	−45 33	152 49	T.	− 8 37	E.S.E.		− 4 39	−13 16		
	−45 33	152 49	R.	− 8 23	E.S.E.		− 4 39	−13 02		
	−45 33	152 49	T.	− 8 25	E.S.E.		− 4 39	−13 04		
	−45 38	152 55	Sm.	− 8 10	E.S.E.	−71 40	− 4 39	−12 49	−13 09	
	−45 38	152 55	R.	− 8 32	E.S.E.		− 4 39	−13 11		
	−45 38	152 55	R.	− 8 22	E.S.E.		− 4 39	−13 01		
	−45 40	153 02	R.	− 8 40	E.S.E.		− 4 39	−13 19		
16 A.M.	−46 05	154 11	T.	− 8 31	S.E. by E. ½ E.		− 4 34	−13 05		
	−46 05	154 11	Y.	− 8 39	S.E. by E. ½ E.		− 4 34	−13 13		
	−46 05	154 11	S.	− 8 56	S.E. by E.		− 4 23	−13 19		
	−46 09	154 14	S.	− 9 17	S.E. by E. ½ E.	−72 04	− 4 34	−13 51	−13 38	
	−46 09	154 14	Y.	− 9 23	S.E. by E. ½ E.		− 4 34	−13 57		
	−46 09	154 14	T.	− 9 40	S.E. by E. ½ E.		− 4 34	−14 14		
	−46 09	154 14	T.	− 8 31	S.E. by E. ½ E.		− 4 34	−13 05		
	−46 15	154 28	S.	− 9 50	S.E. by E. ½ E.		− 4 34	−14 24		
16 P.M.	−46 30	154 54	T.	−13 29	N.		0 00	−13 29		
	−46 30	154 54	S.	−14 55	N. by E.		− 0 46	−15 41		
	−46 30	154 54	T.	−12 57	N.N.E.		− 1 30	−14 27		
	−46 30	154 54	T.	− 8 05	S.E. by E. ½ E.	−72 04	− 4 34	−12 39	−13 58	
	−46 30	154 54	R.	− 9 12	S.E. by E. ½ E.		− 4 34	−13 46		
	−46 30	154 54	R.	− 9 15	S.E. by E. ½ E.		− 4 34	−13 49		
	−46 32	155 01	T.	− 9 19	S.E. by E. ½ E.		− 4 34	−13 53		
18 P.M.	−49 36	160 52	R.	−13 11	E.S.E.					
	−49 42	160 56	R.	−12 27	E.S.E.					
	−49 48	161 00	R.	−11 49	E.S.E.					
	−49 49	161 00	T.	−12 18	E.S.E.	−74 00	− 5 19	−17 16	−17 16	
	−49 49	161 00	T.	−12 03	E.S.E.					
	−49 49	161 00	T.	−12 06	E.S.E.					
	−49 52	161 08	R.	−11 18	E.S.E.					
	−49 52	161 08	S.	−10 27	E.S.E.					
Dec. 5. A.M.	−50 32	166 12	....	−22 29	S.W.	....	+ 4 05	−18 24		
	At anchor.		....	−22 26	S.W.	....	+ 4 05	−18 21		
				−17 49						
				−17 44						
				−17 45						
P.M.	Auckland Island. −50 32	166 12	R.	−17 42	Observed on shore.	....	....	....	−17 44·1	Declination observed on shore with the Magnetometers of the Observatory.
				−17 43						
				−17 42						
	At anchor.			−16 44	S.		0 00	−16 44		
	At anchor.			−16 20	S.S.W.		+ 2 17	−14 03		
8 P.M.	At anchor.		T.	−20 26	N.N.W.		+ 1 39	−18 47		
	At anchor.		T.	−22 35	N.W.		+ 3 10	−19 25		
	At anchor.		T.	−20 17	N.N.W.		+ 1 39	−18 38		
	At anchor.		W.	−19 56	N.N.W. ½ W.		+ 2 03	−17 53		
	At anchor.		T.	−19 54	N.N.W.		+ 1 39	−18 15		
	At anchor.		T.	−15 38	N.N.E.		− 1 39	−17 17		
	At anchor.		T.	−15 46	N.E.		− 3 10	−18 56		
	At anchor.		T.	−13 36	E.N.E.		− 4 23	−17 59		
	At anchor.		T.	−12 52	E.	−73 15	− 5 05	−17 57	−17 53	Mean declination observed on board at anchor.

Observations of Declination. (Continued.)

1840.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′			° ′	° ′	° ′	
Dec. 11. A.M.	Auckland Island. At anchor.		T.	−22 06	W.N.W.	−73 15	+ 4 23	−17 43	− 17 53	
			T.	−21 39	N.W. by W.		+ 3 50	−17 49		
			T.	−22 49	W.		+ 5 05	−17 44		
			T.	−23 19	W. by N.		+ 4 50	−18 29		
			T.	−23 01	W.		+ 5 05	−17 56		
			T.	−22 26	W. by N.		+ 4 50	−17 36		
			T.	−21 32	N.W. ½ N.		+ 2 48	−18 44		
12 A.M.	−50 33	166 24	R.	−12 33	S.E. by E.		− 4 46	−17 19		
	−50 33	166 24	S.	−12 15	S.E. by E. ½ E.		− 4 58	−17 13		
	−50 33	166 24	T.	−12 30	S.E. by E.		− 4 46	−17 16		
	−50 48	166 42	T.	−10 15	S.E. by E.	−73 30	− 4 46	−15 01	−16 03	
	−50 48	166 43	S.	−11 06	S.E. by E.		− 4 46	−15 52		
	−50 48	166 43	Y.	− 9 46	S.E. by E.		− 4 46	−14 32		
13 A.M.	−52 14	166 43	S.	−10 37	S.E. ½ E.		− 4 28	−15 05		
16 P.M.	−52 33	169 09	R.	−22 19	S.W. ½ W.		+ 4 32	−17 47		
	Campbell Island, at anchor.		R.	−23 14	W.S.W.	−73 52	+ 5 17	−17 57	−17 52	
18 A.M.	−54 12	169 06	R.	−15 53	S.S.E.		− 2 29	−18 22		
	−54 12	169 06	S.	−15 41	S.S.E.		− 2 29	−18 10		
	−54 13	169 06	R.	−15 21	S.S.E. ½ E.	−74 46	− 3 00	−18 21	−18 44	
	−54 16	169 06	T.	−17 31	S.S.E.		− 2 29	−20 00		
	−54 16	169 07	S.	−15 42	S.S.E.		− 2 29	−18 11		
19 A.M.	−55 22	169 38	S.	−18 47	S. ½ W.	−75 30	+ 0 40	−18 07		
21 A.M.	−57 25	170 21	Sm.	−20 40	S.S.E.		− 3 01	−23 41		
	−57 25	170 21	T.	−19 39	S.S.E.		− 3 01	−22 40		
	−57 27	170 21	Y.	−20 43	S.S.E.		− 3 01	−23 44	−21 58	
	−57 27	170 21	T.	−18 18	S.S.E.		− 3 01	−21 19		
	−57 31	170 21	Sm.	−20 43	S.S.E.		− 3 01	−23 44		
	−57 35	170 21	S.	−17 09	S.S.E.		− 3 01	−20 10		
	−57 35	170 21	O.	−19 06	S. ½ E.	−77 00	− 0 44	−19 50		
	−57 36	170 21	T.	−20 00	S. by E. ½ E.		− 2 15	−22 15		
	−57 38	170 27	R.	−21 54	S.		0 00	−21 54		
	−57 38	170 27	S.	−17 43	S.S.E.		− 3 01	−20 44	−21 59	
	−57 40	170 28	R.	−24 54	S. ½ E.		− 0 44	−25 38		
	−57 45	170 28	S.	−23 29	S. by W. ½ W.		+ 2 15	−21 14		
	−57 45	170 28	O.	−24 32	S. by W. ½ W.		+ 2 15	−22 17		
22 A.M.	−59 00	170 55	T.	−19 34	S.S.E.	−78 04	− 3 12	−22 46		
	−59 01	170 51	T.	−19 08	S.E. by S.		− 4 29	−23 37		
23 A.M.	−59 36	170 08	T.	−23 25	S. by W. ½ W.		+ 2 30	−20 55		
	−59 45	170 02	Y.	−21 54	S. ¾ W.		+ 1 15	−20 39		
	−59 47	170 02	Y.	−21 12	S. by W.		+ 1 40	−19 32	−21 28	
23 P.M.	−59 42	169 16	R.	−17 57	S.E. by S.	−78 33	− 4 39	−22 36		
	−59 43	169 17	T.	−17 19	S.S.E.		− 3 18	−20 37		
	−49 45	169 19	T.	−15 01	S.E. ¼ E.		− 6 03	−21 04		
24 A.M.	−60 10	170 24	Sm.	−20 07	S.S.E		− 3 21	−23 28		
	−60 10	170 24	T.	−20 17	S. by E.		− 1 43	−22 00		
	−60 10	170 24	T.	−21 33	S.		0 00	−21 33		
	−60 10	170 24	T.	−21 38	S. ¼ W.		+ 0 25	−21 13		
	−60 12	170 24	Y.	−20 01	S.E.		− 6 03	−26 04		
	−60 12	170 24	S.	−18 03	S. by E. ½ E.	−78 53	− 2 30	−20 33	−22 49	
	−60 12	170 24	O.	−20 21	S.S.E.		− 3 21	−23 42		
	−60 12	170 24	T.	−21 27	S. by E.		− 1 43	−23 10		
	−60 18	170 27	R.	−20 13	S.S.E.		− 3 21	−23 34		
	−60 20	170 27	R.	−19 31	S.S.E.		− 3 21	−22 52		

Observations of Declination. (Continued.)

1840.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declina-tion.	Remarks.
	° ′	° ′		° ′			° ′	° ′	° ′	
Dec. 24 P.M.	−60 42	170 55	R.	−16 49	S.E.		− 6 06	−22 55		
	−60 42	170 55	R.	−18 03	S.E. by S.		− 4 52	−22 55		
	−60 46	170 55	R.	−18 06	S.E. by S.		− 4 52	−22 58		
	−60 46	170 55	R.	−18 23	S.E. by S.		− 4 52	−23 15		
	−60 46	170 55	S.	−19 37	S. by E. ½ E.		− 2 40	−22 17		
	−60 46	170 55	T.	−18 42	S.S.E.	−79 06	− 3 25	−22 07	−22 32	
	−60 48	170 55	R.	−18 02	S.E. by S.		− 4 52	−22 54		
	−60 48	170 55	T.	−17 35	S.E. by S.		− 4 52	−22 27		
	−60 48	170 40	S.	−17 33	S.E. by S.		− 4 52	−22 25		
	−60 50	170 44	R.	−17 57	S.E. by S.		− 4 52	−22 49		
	−60 55	170 41	S.	−16 46	S.S.E. ½ E.		− 4 07	−20 53		
29 P.M.	−64 10	172 28	R.	−30 28	S.S.W.		+ 4 06	−26 22		
	−64 10	172 28	R.	−29 24	S.S.W.		+ 4 06	−25 18		
	−64 10	172 28	R.	−27 34	S. by W.	−81 03	+ 2 06	−25 28		
	−64 12	172 29	Sm.	−25 30	S. ½ W.		+ 1 02	−24 28		
	−64 12	172 29	S.	−25 32	S. ½ W.		+ 1 02	−24 30	−25 33	
	−64 12	172 29	S.	−23 32	S.E.		− 7 24	−30 56		
30 A.M.	−64 27	172 36	S.	−30 04	S.W. ½ S.		+ 6 44	−23 20		
	−64 27	172 36	S.	−31 18	S.W. ½ S.	−81 11	+ 6 44	−24 34		
	−64 27	172 36	T.	−32 36	S.W.		+ 7 30	−25 06		
	−64 37	172 40	Y.	−31 01	S.W. ½ W.		+ 8 04	−22 57		
	−64 37	172 40	Sm.	−31 54	S.S.W.		+ 4 11	−27 43		
	−64 37	172 40	R.	−23 26	S.		0 00	−23 26		
	−64 37	172 40	T.	−24 08	S.		0 00	−24 08		
	−64 37	172 40	S.	−26 01	S.	−81 16	0 00	−26 01	−25 57	
30 P.M.	−64 44	172 50	R.	−25 03	S.S.E.		− 4 11	−29 14		
	−64 46	172 50	R.	−23 04	S.S.E.		− 4 11	−27 15		
	−64 48	172 50	R.	−22 43	S.S.E.		− 4 11	−26 54		
31 A.M.	−65 22	172 25	S.	−22 13	S.S.E.		− 4 25	−26 38		
	−65 22	172 25	O.	−19 39	S.S.E. ½ E.		− 5 24	−25 03		
	−65 23	172 21	S.	−22 06	S. by E. ½ E.		− 3 20	−25 26		
	−65 25	172 21	O.	−21 33	S. by E.		− 2 15	−23 48	−25 06	
	−65 25	172 21	S.	−22 15	S. by E.	−81 45	− 2 15	−24 30		
	−65 30	172 16	T.	−22 36	S. by E.		− 2 15	−24 51		
	−65 30	172 16	T.	−23 00	S. ½ E.		− 1 05	−24 05		
	−65 31	172 16	Y.	−27 33	S. ½ W.		+ 1 05	−26 28		
	−65 31	172 16	S.	−22 33	S.		0 00	−22 33		
	−65 32	172 14	T.	−24 02	S.		0 00	−24 02		
31 P.M.	−66 04	171 34	T.	−29 03	S.		0 00	−29 03		
	−66 07	171 34	Sm.	−29 23	S. ½ W.		+ 1 13	−28 10	−27 11	
	−66 07	171 34	S.	−30 05	S. ½ W.		+ 1 13	−28 52		
	−66 07	171 34	T.	−30 38	S. ½ W.		+ 1 13	−29 25		
	−66 09	171 32	R.	−30 39	S. by W.	−82 30	+ 2 30	−28 09		
1841.										
Jan. 1 A.M.	−66 09	171 32	W.	−35 45	N.W. by W.		+ 9 18	−26 27		
1 P.M.	−66 20	170 32	S.	−32 20	S.S.W.		+ 4 50	−27 30		
	−66 28	170 48	R.	−32 44	S.S.W.		+ 4 50	−27 54		
2 A.M.	−66 20	169 13	T.	−20 18	S.E.		− 8 47	−29 05		
	−66 20	169 13	T.	−17 35	E.S.E.		−11 11	−28 46	−28 21	
	−66 20	169 13	Sm.	−22 21	S.E.		− 8 47	−31 08		
	−66 20	169 13	T.	−18 44	S.E. by E.		−10 11	−28 55		
	−66 20	169 13	Y.	−17 53	S.E. by E.		−10 11	−28 04		
	−66 20	169 41	S.	−17 08	S.E. by E.		−10 11	−27 19		
	−66 20	169 41	T.	−17 01	E.S.E.		−11 11	−28 12		
	−66 20	169 43	R.	−16 33	E.S.E.		−11 11	−27 44		
	−66 24	169 44	R.	−17 52	E.S.E.	−82 30	−11 11	−29 03	−27 21	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
Jan. 2 A.M.	−66° 30′	169° 44′	T.	−35° 14′	W.N.W. ½ W.	−82 30	+10° 55′	−24° 19′	−27° 21′	
	−66 30	169 44	W.	−35 45	N.W. by W.		+ 9 18	−26 27		
	−66 30	169 46	R.	−35 31	N.W. by W.		+ 9 18	−26 13		
	−66 30	169 46	S.	−34 28	N.N W. ½ W.		+ 5 11	−29 17		
	−66 29	169 48	O.	−31 46	N.N.W.		+ 4 11	−27 35		
4 A.M.	−65 28	171 47	S.	−20 09	S.E. by S.		− 6 35	−26 44		
	−65 28	171 47	O.	−18 33	S.E.		− 8·15	−26 48		
	−65 28	171 47	W.	−19 43	S.E. by E.		− 9 33	−29 16		
	−65 28	171 47	T.	−17 46	E. by S. ¾ S.		−10 38	−28 24		
	−65 28	171 47	T.	−17 28	E. by S. ¾ S		−10 38	−28 06		
	−65 28	171 56	W.	−16 43	E. by S. ½ S.	−82 0	−10 45	−27 28	−27 34	
4 P.M.	−65 26	172 50	R.	−15 21	S. 79° E.		−11 00	−26 21		
	−65 26	172 50	R.	−15 44	S. 74° E.		−10 45	−26 29		
	−65 26	173 06	T.	−16 14	E. by S.		−11 00	−27 14		
	−65 26	173 06	T.	−17 00	E.S.E.		−10 30	−27 30		
	−65 27	173 32	R.	−18 22	S. 67° E.		−10 30	−28 52		
	−65 27	173 32	W.	−14 08	E.S.E.		−10 12	−24 20		
	−65 27	173 32	R.	−17 26	S. 72° E.		−10 17	−27 43		
	−65 27	173 32	R.	−18 59	S. 63° E.		− 9 45	−28 44		
	−65 27	173 32	Sm.	−18 35	E.S.E.		−10 12	−28 47		
	−65 27	173 32	T.	−17 55	E.S.E.	−81 45	−10 12	−28 07	−28 08	
	−65 29	173 55	R.	−18 08	S. 68° E.		−10 12	−28 20		
	−65 30	173 55	R.	−19 42	S.E. by E. ½ E.		− 9 45	−29 27		
	−65 40	173 55	Y.	−19 16	S.E. ½ E.		− 8 38	−27 54		
	−65 32	173 55	T.	−23 49	S. by E. ½ E.		− 3 21	−27 10		
	−65 34	173 55	R.	−22 48	S.E.		− 7 56	−30 44		
5 A.M.	−66 39	174 14	Y.	−29 46	S.E. by S.	−82 30	− 7 04	−36 50		
	−66 39	174 14	Sm.	−21 41	S.E.		− 8 47	−30 28		
5 P.M.	−67 12	174 41	R.	−28 05	S.S.E.		− 5 11	−33 16		
	−67 12	174 42	T.	−29 49	S. by E.		− 2 42	−32 31		
	−67 12	174 42	Y.	−30 10	S. ¾ E.		− 2 01	−32 11		
	−67 12	174 42	Y.	−27 59	S.S.E. ½ E.		− 6 25	−34 24		
	−67 23	174 42	R.	−18 03	E.S.E.		−11 57	−30 00		
	−67 23	174 42	T.	−17 25	E.S.E.		−11 57	−29 22		
	−67 23	174 42	T.	−18 05	S.E. by E.	−83 00	−10 53	−28 58	−31 29	
	−67 23	174 42	T.	−17 13	E.S.E.		−11 57	−29 10		
	−67 23	174 42	R.	−18 07	E.S.E.		−11 57	−30 04		
	−67 27	174 42	R.	−18 44	E.S.E.		−11 57	−30 41		
	−67 28	174 51	R.	−21 06	S.E.		− 9 23	−30 29		
	−67 28	174 51	T.	−26 53	S.S.E.		− 5 11	−32 04		
	−67 29	174 51	R.	−29 42	S. ¾ E.		− 2 01	−31 43		
	−67 30	174 51	R.	−26 31	S.S.E.		− 5 11	−31 42		
6 A.M.	−67 50	175 00	O.	−29 01	S.S.E.		− 5 33	−34 34		
	−67 50	175 00	S.	−29 09	S.S.E.		− 5 33	−34 42		
	−67 52	175 01	S.	−31 48	S.S.E.		− 5 33	−37 21		
	−67 52	175 01	O.	−27 53	S.S.E.		− 5 33	−33 26		
	−68 00	175 00	T.	−26 11	S.S.E. ½ E.		− 6 46	−32 57		
	−68 00	175 00	Y.	−27 00	S.S.E.		− 5 33	−32 33		
	−68 00	175 00	S.	−27 01	S.S.E.	−83 30	− 5 33	−32 34	−34 04	
	−68 00	175 00	T.	−27 42	S.S.E.		− 5 33	−33 15		
	−68 05	175 10	W.	−26 58	S.S.E. ½ E.		− 6 46	−33 44		
	−68 05	175 10	T.	−28 18	S.S.E.		− 5 33	−33 51		
	−68 05	175 14	R.	−29 51	S.S.E.		− 5 33	−35 24		
	−68 05	175 14	R.	−43 7	N.W.		+ 9 09	−34 38		
	−68 12	175 14	R.	−24 56	S.E. ½ S.		− 9 02	−33 58		

Observations of Declination. (Continued.)

1841.	Position.		Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	Lat.	Long.								
Jan. 7 P.M.	° ′ −68 32	° ′ 175 49	T.	° ′ −46 02	W. ¾ N.		° ′ +13 25	° ′ −32 37	° ′	
	−68 32	175 49	T.	−47 05	W. by S. ½ S.		+13 20	−33 45		
	−68 32	175 49	W.	−46 07	W. by S.		+13 39	−32 28		
	−68 32	175 49	Sm.	−24 06	S.E. ½ E.		−11 02	−35 08		
	−68 32	175 49	T.	−46 57	W. by S.		+13 39	−33 18		
	−68 32	175 49	R.	−25 49	S.E. ½ S.	−83 35	− 9 12	−35 01	−33 52	
	−68 32	175 49	R.	−47 29	W. by S. ½ S.		+13 20	−34 09		
	−68 32	175 55	T.	−30 21	S. by E. ¾ E.		− 5 30	−35 51		
8 A.M.	−68 30	176 35	T.	−20 22	S.E. by E. ¾ E.		−12 44	−33 06		
	−68 30	176 35	S.	−20 51	E. ¾ N.		−13 25	−34 16		
	−68 30	176 35	T.	−20 22	E. by S. ¾ S.		−13 10	−33 32		
	−68 30	176 35	Y.	−19 58	E. by S. ½ S.		−13 20	−33 18		
8 P.M.	−68 28	176 32	R.	−34 39·1	. . . .	. . . .	. . . .	. . . .	−34 39·1	Observed on ice.
9 A.M.	−68 55	176 24	S.	−29 26	S.S.E.		− 5 45	−35 11		
	−68 55	176 24	Y.	−29 38	S.S.E.		− 5 45	−35 23		
	−68 55	176 24	O.	−28 49	S.S.E.	−83 45	− 5 45	−34 34	−34 58	
	−68 55	176 18	T.	−29 09	S.S.E.		− 5 45	−34 54		
	−68 55	176 18	W.	−29 04	S.S.E.		− 5 45	−34 49		
10 P.M.	−70 31	173 17	R.	−41 12	S.		0 00	−41 12		
	−70 32	172 56	R.	−47 04	S. 27° W.		+ 8 34	−38 30		
	−70 34	172 53	R.	−47 35	S. 25° W.	−85 02*	+ 8 00	−39 35	−39 35	
	−70 34	172 53	S.	−49 34	S.S.W. ½ W.		+ 8 43	−40 51		
	−70 34	172 52	R.	−59 05	W.		+17 50	−41 12		
	−70 34	172 52	R.	−49 12	S.W.		+13 03	−36 09		
11 A.M.	−70 52	172 25	T.	−44 19	S.		0 00	−44 19		
	−70 52	172 25	Y.	−44 35	S.		0 00	−44 35		
	−70 55	172 27	Sm.	−45 31	S.		0 00	−45 31		
	−71 02	172 27	T.	−43 11	S.		0 00	−43 11		
	−71 02	172 27	Sm.	−43 48	S.	−85 50	0 00	−43 28	−43 56	
	−71 02	172 27	T.	−46 48	S. ½ W.		+ 2 08	−44 40		
	−71 02	172 27	S.	−43 43	S.		0 0	−43 43		
	−71 02	172 27	O.	−44 36	S. ½ W.		+ 2 08	−42 28		
	−71 12	172 15	R.	−43 29	S.		0 0	−43 29		
11 P.M.	−71 21	170 52	R.	−48 45	S. by W.		+ 4 20	−44 25		
	−71 21	170 52	T.	−50 10	S. by W. ½ W.		+ 6 28	−43 42		
	−71 21	170 52	W.	−47 35	S. by W. ½ W.		+ 6 28	−41 07		
	−71 21	170 52	Y.	−51 03	S. by W. ½ W.		+ 6 28	−44 35		
	−71 22	170 56	T.	−51 09	S. by W. ½ W.	−85 53	+ 6 28	−44 41	−44 01	
	−71 22	170 56	S.	−47 45	S. by W.		+ 4 20	−43 25		
	−71 22	170 56	O.	−49 33	S. by W. ½ W.		+ 6 28	−43 05		
	−71 24	170 56	T.	−51 42	S. by W. ½ W.		+ 6 28	−45 14		
	−71 24	170 56	S.	−59 57	S.W.		+15 50	−44 07		
	−71 19	171 06	T.	−28 17	N.E. by E.		−17 36	−45 53		
12 P.M.	−71 52	171 11	S.	−27 44	N.E. ½ N.		−13 38	−41 22		
	−71 52	171 11	W.	−30 36	N.E. ½ N.		−13 38	−44 14		
13 P.M.	−72 07	172 18	S.	−27 40	E. by N. ½ N.		−21 06	−48 46		
15 A.M.	−71 46	171 57	O.	−49 22	S. by W. ½ W.		+ 6 40	−42 42		
	−71 46	171 57	S.	−48 22	S. by W. ½ W.	−86 00	+ 6 40	−41 42	−44 24	
	−71 46	171 55	T.	−51 34	S. by W. ½ W.		+ 6 40	−44 54		
	−71 46	171 55	S.	−51 24	S.S.W.		+ 8 52	−42 32		
	−71 54	172 17	T.	−24 13	E. by S.		−22 11	−46 24		
	−71 54	172 17	R.	−24 51	E. by S.		−22 11	−47 02		
	−71 54	172 17	T.	−25 00	E. by S.		−22 11	−47 11		
	−71 54	172 17	W.	−23 32	E. by S. ½ S.		−21 36	−45 08		
	−71 55	172 17	R.	−24 15	E. ½ S.	−86 00	−22 19	−46 34	−48 12	

$$\left.\begin{array}{l} {}^{*}\ \psi' \text{ at West} = -59^\circ\ 05' \\ \psi' \text{ at South} = -41\ \ \ 12 \end{array}\right\} \text{Diff. } 17^\circ\ 53' = \text{ship's attraction at West:}$$

$$\frac{\sin 17^\circ\ 53'}{a} = \tan\theta\,;\ \frac{\sin 17^\circ\ 53'}{\cdot 0267} = 1\cdot 150 = \tan 85^\circ\ 02'.$$

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
Jan. 15 P.M.	−71° 53′	172° 01′	S.	−29° 28′	E. ½ S.	−86° 00′	−22° 19′	−51° 47′	−48° 12′	
	−71 53	172 01	O.	−27 43	E. ¾ N.		−22 00	−49 43		
	−71 53	172 01	T.	−25 33	E. ½ N.		−22 08	−47 41		
	−71 53	172 01	W.	−26 08	E.		−22 27	−48 35		
	−71 58	171 36	R.	−59 31	S.S.W. ½ W.		+10 50	−48 41		
	−72 00	171 32	R.	−26 05	E. ½ S.		−22 19	−48 24		
17 P.M.	−72 14	174 00	W.	−33 28	S.E. by E.		−19 02	−52 30		
	−72 15	174 02	T.	−31 37	S.E. ¾ E.		−18 20	−49 57		
	−72 16	174 10	T.	−32 41	S.E. ½ E.		−17 40	−50 21		
	−72 17	174 14	T.	−35 05	S.E. ½ E.	−86 00	−17 40	−52 45	−51 41	
	−72 17	174 14	S.	−35 58	S.E. ½ E.		−17 40	−53 38		
	−72 17	174 14	O.	−33 15	S.E. ½ E.		−17 40	−50 55		
18 P.M.	−73 00	176 14	R.	−35 12	E.S.E.		−22 02	−57 14		
	−73 02	176 10	T.	−65 04	S.W. by S.		+13 23	−51 41		
	−73 02	176 10	R.	−64 35	S.W. by S.		+13 23	−51 12		
	−73 02	176 10	S.	−65 52	S.W. by S.		+13 23	−52 29		
	−73 02	176 10	O.	−65 50	S.S.W. ½ W.		+11 18	−54 32		
	−73 02	176 03	R.	−65 54	S.W. by S.		+13 23	−52 31		
	−73 02	176 03	T.	−68 09	S.W. ½ S.	−86 10	+15 11	−52 58	−52 41	
	−73 02	175 57	R.	−65 02	S.S.W. ½ W.		+11 18	−53 44		
	−73 02	175 51	R.	−63 34	S.S.W. ½ W.		+11 18	−52 16		
	−73 01	175 38	R.	−63 37	S.W. by S.		+13 23	−50 14		
	−73 00	175 24	R.	−62 45	S.S.W. ½ W.		+11 18	−51 27		
	−72 59	175 11	R.	−64 15	S.S.W. ¾ W.		+12 22	−51 53		
19 A.M.	−72 36	173 40	T.	−66 21	S.W.		+16 15	−50 06		
	−72 36	173 40	W.	−66 12	S.W. ½ W.		+17 37	−48 35		
	−72 36	173 40	Y.	−64 49	S.W. by S.	−86 00	+12 49	−52 00	−50 31	
	−72 36	173 40	T.	−64 11	S.W. ¾ S.		+13 45	−50 26		
	−72 35	173 39	T.	−67 43	S.W.		+16 15	−51 28		
19 P.M.	−72 31	173 40	O.	−53 57	N. by W. ½ W.		+ 6 27	−47 30		
	−72 34	173 42	T.	−43 53	S. by E. ½ E.		− 6 55	−50 48		
	−72 34	173 42	T.	−44 43	S. by E. ½ E.		− 6 55	−51 38		
	−72 34	173 45	Y.	−41 10	S.S.E.	−86 10	− 9 14	−50 24	−51 54	
	−72 34	173 45	O.	−43 34	S.S.E.		− 9 14	−52 48		
	−72 34	173 45	R.	−43 43	S.S.E.		− 9 14	−52 57		
	−72 36	173 40	R.	−48 22	S. by E.		− 4 39	−53 01		
	−72 50	173 10	R.	−49 15	S. by E. ½ E.		− 6 55	−56 10		
21 A.M.	−74 10	169 28	S.	−34 25	E. ¾ S.		−28 37	−63 02		
	−74 10	169 28	O.	−31 47	E. ¼ S.		−28 53	−60 40		
22 A.M.	−73 53	170 57	S.	−88 12	W. by N. ½ N.		+27 11	−61 01		
	−73 53	170 57	S.	−78 56	N.N.W.		+10 28	−68 28		
	−73 53	170 57	S.	−35 43	E. by N.		−28 08	−63 51		
	−73 57	171 40	T.	−48 46	N.N.E. ¾ E.	−86 50	−14 12	−62 58	−63 38	
	−73 57	171 40	T.	−38 00	E. by N.		−28 08	−66 08		
	−73 57	171 40	T.	−36 56	E. ¾ N.		−28 22	−65 18		
	−73 54	171 55	Y.	−37 13	E. by S.		−28 29	−65 42		
	−73 54	171 55	T.	−35 59	E. by S. ½ S.		−27 41	−63 40		
	−73 54	172 00	O.	−31 25	E. by S. ½ S.		−27 41	−59 06		
	−73 55	172 04	O.	−36 52	E.S.E.		−26 53	−63 45		
22 P.M.	−73 58	172 16	S.	−61 29	S.		0 00	−61 29		
	−73 59	171 58	S.	−65 50	S. by W.		+ 5 39	−60 11		
	−73 59	171 58	T.	−67 45	S. ½ W.		+ 2 49	−64 56		
	−74 00	171 43	R.	−66 08	S. by W.		+ 5 39	−60 29		
	−74 00	171 43	R.	−69 22	S. by W.		+ 5 39	−63 43		
	−74 01	171 34	R.	−38 31	E. ½ S.	−86 50	−28 45	−67 16	−64 25	
	−74 04	171 27	R.	−40 04	E. by S. ½ S.		−27 41	−67 45		
	−74 04	171 27	T.	−36 00	E. ¾ S.		−28 37	−64 37		
	−74 04	171 27	W.	−38 52	E. ½ N.		−28 33	−67 25		
	−74 04	171 27	T.	−37 46	E. by S.		−28 29	−66 15		

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Jan. 25 A.M.	−74 36	168 06	T.	− 78 32	S. by W. ½ W.		+ 9 21	− 69 11		
	−74 36	168 06	T.	− 77 36	S. by W. ½ W.		+ 9 21	− 68 15		
	−74 36	168 06	T.	− 37 17	S.E. by E. ¾ E.		−31 38	− 68 55		
	−74 40	169 38	T.	− 37 25	S.E. by E.	−87 20	−29 07	− 66 32	− 69 47	
	−74 41	169 42	Y.	− 39 15	E.S.E.		−32 28	− 71 43		
	−74 41	169 42	Sm.	− 39 54	S.E. by E. ½ E.		−30 45	− 70 39		
	−74 41	169 42	T.	− 43 14	S.E. by E. ¼ E.		−30 00	− 73 14		
25 P.M.	−74 45	169 32	R.	− 81 36	S.S.W.		+12 23	− 69 13		
	−74 45	169 32	R.	− 81 08	S.S.W.		+12 23	− 68 45		
	−74 47	168 51	R.	− 86 28	S.S.W. ½ W.		+15 13	− 71 15		
	−74 47	168 51	S.	− 87 19	S.S.W.		+12 23	− 74 56		
	−74 47	168 51	T.	− 85 35	S. by W. ½ W.		+15 13	− 70 22		
	−74 44	168 22	R.	− 85 15	S.S.W.	−87 10	+12 23	− 72 52	− 71 08	
	−74 44	168 22	R.	− 93 49	S.W. ½ W.		+25 10	− 68 39		
	−74 44	168 10	T.	− 91 01	S.W. by S.		+20 33	− 70 28		
	−74 40	168 08	R.	− 43 39	S.E. ½ E.		−25 10	− 68 49		
26 A.M.	−74 55	168 25	T.	− 94 09	S.W. by S.		+18 03	− 76 06		
27 A.M.	−75 44	168 50	S.	− 75 49	S.S.E.		−15 04	− 90 53		
	−75 44	168 50	T.	− 77 04	S.S.E.		−15 04	− 92 08		
	−75 44	168 50	S.	−100 55	S.S.W. ½ W.		+18 32	− 82 23		
	−75 36	168 23	R.	−100 26	S.S.W.		+15 04	− 85 22		
	−75 36	168 23	Y.	− 99 06	S.S.W.	−87 40	+15 04	− 84 02	− 84 58	
	−75 36	168 23	T.	− 45 19	E.S.E.		−37 42	− 83 01		
	−75 36	168 23	R.	− 46 18	S.E. by E. ½ E.		−35 40	− 81 58		
	−75 36	168 23	S.	− 47 55	S.E. by E. ½ E.		−35 40	− 83 35		
	−75 38	168 33	R.	− 47 41	S.E. by E.		−33 37	− 81 18		
29 A.M.	−77 37	175 43	Sm.	−104 19	N. ½ E.		− 2 48	−107 07		
	−77 40	175 59	T.	−105 44	N. ¼ W.		+ 1 24	−104 20		
	−77 40	175 59	T.	−114 11	N. by W. ½ W.		+ 8 20	−105 51		
	−77 43	176 00	T.	−118 53	N.N.W. ½ W.	−87 00	+13 38	−105 15	−104 25	
	−77 43	176 00	S.	−108 20	N. by W. ½ W.		+ 8 20	−100 00		
	−77 43	176 00	T.	−116 26	N. by W. ½ W.		+ 8 20	−108 06		
	−77 43	176 00	T.	−104 30	N. ¾ W.		+ 4 12	−100 18		
29 P.M.	−77 49	177 30	T.	− 90 54	S.E. by S.		−15 22	−106 16		
	−77 49	177 46	T.	−104 52	N. ¼ W.	−86 40	+ 1 15	−103 37	−105 21	
	−77 50	178 13	R.	−110 07	N. ½ W.		+ 2 30	−107 37		
	−77 51	178 33	R.	−100 10	N. ¾ E.		− 3 45	−103 55		
30 A.M.	−77 47	180 34	S.	−106 52	N.N.W. ½ W.	−86 20	+10 35	− 96 17	− 96 17	
31 A.M.	−77 37	186 41	S.	− 70 55	N.E. ½ N.		−13 39	− 84 34		
	−77 50	188 00	T.	− 60 57	N.E. by E. ¼ E.		−19 13	− 80 10		
	−77 50	188 00	T.	− 66 38	N E. by N.		−11 58	− 78 36		
	−77 50	188 00	Sm.	− 68 56	N.N.E.		− 8 10	− 77 06		
31 P.M.	−77 08	189 57	S.	− 72 35	N.N.E. ½ E.		−10 04	− 82 39		
	−77 08	189 57	R.	− 74 06	N.N.E. ½ E.	−86 00	−10 04	− 84 10	− 82 29	
Feb. 1 A.M.	−77 11	189 01	Sm.	−103 58	S.W. by W. ½ W.		+20 02	− 83 56		
	−77 11	189 01	T.	−102 56	S.W. by W.		+19 02	− 83 54		
	−77 11	189 00	T.	−103 52	W. by S. ½ S.		+21 36	− 82 16		
	−77 11	189 00	T.	− 90 06	N.N.W.		+ 8 10	− 81 56		
	−77 11	189 00	O.	− 70 58	S.E. by S.		−12 49	− 83 47		
	−77 08	189 05	S.	− 73 58	S.E. by S.		−12 49	− 86 47		
1 P.M.	−77 08	188 26	R.	− 85 52	S. by E.		− 4 17	− 90 09		
	−77 08	188 26	R.	− 84 25	S.S.E.		− 8 30	− 92 55		
	−77 09	188 24	R.	− 79 49	S.E. by S.		−12 18	− 92 07		
	−77 09	188 24	R.	− 66 58	E. ¼ S.	−85 50	−21 27	− 88 25	− 91 07	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
Feb. 1 P.M.	−77 09	188 24	R.	− 70 19	E.S.E.	−85 50	−20 13	−90 32	−91 07	
	−77 09	188 24	R.	− 75 38	S.E.		−15 37	−91 15		
	−77 09	188 24	R.	− 82 22	S.S.E.		− 8 30	−90 52		
	−77 09	188 15	R.	− 79 56	S.E. by S.		−12 18	−92 14		
	−77 09	188 15	T.	− 79 14	S.E. by S.		−12 18	−91 32		
2 A.M.	−77 34	186 56	S.	− 72 39	E.S.E.		−22 02	−94 41		
	−77 34	186 03	O.	− 70 42	S.E. by E. ½ E.		−20 58	−91 40		
	−77 34	186 15	S.	− 69 05	E.		−23 36	−92 41		
	−77 34	186 15	O.	− 71 39	E.S.E.		−22 02	−93 41		
	−77 35	186 55	T.	− 72 32	S.E. by E. ¼ E.	−86 10	−20 27	−92 59	−93 22	
	−77 35	186 55	T.	− 73 09	S.E. by E. ½ E.		−20 58	−94 07		
	−77 35	186 55	T.	− 75 37	S.E.		−17 00	−92 37		
	−77 35	186 55	S.	− 76 49	S.E.		−17 00	−93 49		
	−77 43	186 50	W.	− 72 04	E.S.E.		−22 02	−94 06		
2 P.M.	−77 45	187 00	R.	− 69 50	S.E. by E.		−19 55	−89 45		
	−77 45	187 00	R.	− 72 25	S.E. by E. ½ E.		−20 58	−93 23		
	−77 47	186 52	T.	− 69 57	E. by S. ½ S.		−22 39	−92 36		
	−77 47	186 52	Sm.	− 72 53	E.S.E.	−86 10	−22 02	−94 55	−94 14	
	−77 45	186 52	R.	− 73 10	E.S.E.		−22 02	−95 12		
	−77 45	186 52	R.	− 72 56	E. by S. ½ S.		−22 39	−95 35		
	−77 46	186 51	S.	− 74 47	E.S.E.		−22 02	−96 49		
	−77 46	186 51	T.	− 74 38	S.E. by E. ½ E.		−20 58	−95 36		
	−77 47	186 51	R.	− 75 01	E.S.E.		−22 02	−97 03		
	−77 56	186 51	R.	− 74 22	E.		−23 36	−97 58		
	−77 56	186 51	T.	− 72 32	E. ½ N.		−23 16	−95 48		
	−77 57	186 44	R.	− 71 21	E.		−23 36	−94 57		
	−77 57	186 44	R.	− 75 38	E.N.E.	−86 10	−21 23	−97 01	−96 14	
	−77 57	186 44	T.	− 74 27	E ¼ N.		−23 26	−97 53		
	−77 59	186 47	R.	− 72 03	E.		−23 36	−95 39		
	−78 00	186 45	R.	− 72 10	E.S.E.		−22 02	−94 12		
3 A.M.	−77 32	186 00	Sm.	−117 40	W. by S. ½ S.		+22 40	−95 00		
	−77 32	186 00	T.	−118 47	W.S.W.		+22 02	−96 45		
4 A.M.	−77 05	192 32	S.	− 77 52	S. by E.		− 4 18	−82 10		
	−77 06	192 33	T.	− 77 44	S. ¼ E.		− 1 04	−78 48		
	−77 06	192 33	O.	− 76 31	S. ½ E.		− 2 08	−78 39		
	−77 54	192 30	Y.	− 62 21	E.N.E.	−85 50	−19 31	−81 52		
	−77 54	192 30	S.	− 60 36	E.N.E.		−19 31	−80 07		
	−77 54	192 30	O.	− 63 11	N.E. by E.		−17 24	−80 35		
	−76 57	192 37	T.	− 59 54	N.E. by E. ½ E.		−18 27	−78 21	−81 50	
4 P.M.	−77 6	192 34	R.	− 61 29	E. by N. ½ N.		−19 24	−80 53		
	−77 9	192 43	R.	− 62 14	E. by N.		−20 04	−82 18		
	−77 9	192 43	T.	− 62 31	E. by N.	−85 40	−20 04	−82 35		
	−77 13	192 51	R.	− 68 53	E. by N. ½ N.		−19 24	−88 17		
	−77 13	192 51	T.	− 67 45	N.E. by E. ¾ E.		−18 13	−85 58		
	−77 13	192 49	R.	− 93 17	S.S.W. ½ W.		+10 00	−83 17		
5 A.M.	−77 24	192 56	S.	− 81 22	S.		0 00	−81 22		
	−77 8	192 59	O.	− 63 33	E.		−20 38	−84 11		
	−77 8	192 59	T.	− 77 06	S. by E.	−85 40	− 4 08	−81 14	−82 26	
	−77 8	192 59	T.	− 83 12	S.		0 00	−83 12		
	−77 8	192 59	T.	− 92 23	S.S.W. ½ W.		+10 01	−82 22		
	−77 8	192 59	W.	− 92 16	S.S.W. ½ W.		+10 01	−82 15		
	−77 19	192 50	T.	− 83 00	S. ¼ W.		+ 1 00	−82 00		
5 P.M.	−77 16	191 32	R.	− 89 26	S. by W. ½ W.		+ 6 10	−83 16		
	−77 16	191 32	R.	− 80 06	S. by E. ½ E.	−85 40	− 6 10	−86 16	−83 56	
	−77 16	191 32	R.	− 70 42	S.E. ½ S.		−13 26	−84 08		
	−77 16	191 32	R.	− 63 24	E. ½ S.		−20 30	−83 54		
	−77 16	191 32	R.	− 66 30	S.E. by E.		−17 34	−84 04		

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Feb. 6 A.M.	−77 14	190 2	S.	− 87 49	s. by w.		+ 4 28	− 83 21		
	−77 05	189 2	T.	− 88 18	s. by w.		+ 4 28	− 83 50		
	−77 09	188 50	Sm.	− 83 07	s. ¾ w.	−86 00	+ 3 20	− 79 47	−82 09	
	−77 09	188 50	T.	− 85 52	s. ¾ w.		+ 3 20	− 82 32		
	−77 09	188 50	T.	− 58 23	e. by n.		−21 50	− 80 13		
	−77 04	188 40	T.	− 80 58	s. ½ e.		− 2 14	− 83 12		
7 A.M.	−76 58	186 40	T.	− 94 54	s.s.w. ¼ w.		+10 02	− 84 52		
	−76 58	186 40	T.	− 91 17	s.s.w.		+ 9 02	− 82 15		
	−76 58	186 40	T.	− 87 10	s. by w. ½ w.		+ 6 45	− 80 25		
	−76 58	186 40	T.	− 59 46	e. ½ s.		−22 52	− 82 38		
	−76 56	186 39	S.	− 59 16	e. ½ s.	−86 05	−22 52	− 82 08	−81 33	
	−76 56	186 39	O.	− 56 07	e. ¼ n.		−22 53	− 79 00		
	−76 56	186 39	T.	− 57 38	e. ½ s.		−22 52	− 80 30		
	−76 56	186 39	O.	− 57 12	e. by s.		−22 43	− 79 55		
	−76 57	186 36	S.	− 60 09	e. by s. ½ s.		−22 06	− 82 15		
7 P.M.	−77 11	187 03	T.	− 68 38	e. by s. ¼ s.		−21 54	− 80 32		
	−77 11	187 03	R.	− 68 31	e. by s. ½ s.		−21 36	− 90 07		
	−77 12	187 03	T.	− 70 01	s.e. by e. ½ e.		−20 02	− 90 03		
	−77 12	187 03	T.	− 66 16	s.e. by e.		−19 02	− 85 18		
	−77 12	187 03	R.	− 67 27	s.e. by e.	−86 00	−19 02	− 86 29	−87 29	
	−77 12	187 03	R.	− 81 21	s.s.e.		− 8 52	− 90 13		
	−77 14	187 01	R.	− 74 43	s.e. by s.		−12 49	− 87 32		
	−77 14	187 01	R.	− 72 20	s.e.		−16 15	− 88 35		
	−77 14	187 01	T.	− 72 00	s.e.		−16 15	− 88 15		
	−77 13	186 54	W.	− 71 29	s.e.		−16 15	− 87 44		
8 A.M.	−77 24	186 19	S.	− 65 24	e.s.e.		−21 02	− 86 26		
	−77 24	186 19	O.	− 65 32	e.s.e.		−21 02	− 86 34		
	−77 21	186 22	T.	− 68 19	e. by s. ½ s.	−86 00	−21 37	− 89 56	−89 19	
	−77 21	186 22	Y.	− 67 35	e. ½ s.		−22 19	− 89 54		
	−77 21	186 22	Y.	− 71 43	e.s.e.		−21 02	− 92 45		
	−77 21	186 22	T.	− 69 19	e.s.e.		−21 02	− 90 21		
	−77 21	186 22	O.	− 67 29	e.s.e.		−21 02	− 88 31		
	−77 21	186 22	S.	− 67 38	e.s.e.		−21 02	− 88 40		
	−77 30	186 40	T.	− 71 42	e.s.e.	−86 00	−21 02	− 91 44	−90 21	
	−77 30	186 40	W.	− 70 31	e.s.e.		−21 02	− 91 33		
	−77 30	186 40	T.	− 69 39	e.		−22 27	− 92 06		
	−77 37	186 36	R.	− 67 40	e. by n.		−21 50	− 89 30		
8 P.M.	−77 47	187 18	R.	− 72 51	e. by n. ½ n.		−21 6	− 93 57		
	−77 47	187 10	S.	− 74 04	e.n.e.		−20 23	− 94 27		
	−77 48	187 29	O.	− 74 17	e.n.e.	−86 00	−20 23	− 94 40	−95 52	
	−77 48	187 29	T.	− 75 35	e.n.e.		−20 23	− 95 58		
	−77 50	187 35	T.	− 76 38	n.e. by e. ½ e.		−19 18	− 95 56		
	−77 50	187 35	W.	− 79 50	e.n.e.		−20 23	−100 13		
	−77 49	187 25	R.	− 76 04	e.n.e.		−20 23	− 96 27		
	−77 49	187 25	T.	− 79 29	n.e. by e.		−18 11	− 97 40		
	−77 50	187 31	R.	− 75 32	n.e. by e.	−86 00	−18 11	− 93 43	−96 00	
	−77 51	187 36	R.	− 77 19	n.e. by e. ½ e.		−19 18	− 96 37		
	−77 53	187 44	R.	− 80 42	n.e.		−15 20	− 96 02		
	−77 57	188 06	T.	− 95 31	n.		0 00	− 95 31		
9 A.M.	−77 52	191 16	W.	−108 01	s.w. ½ s.		+13 57	− 94 04		
	−77 52	191 16	T.	−109 17	s.w. ½ s.		+13 57	− 95 20		
	−77 52	191 07	Y.	−108 43	s.w. ½ s.	−85 50	+13 57	− 94 46	−93 43	
	−77 52	191 07	T.	−103 50	s.w. by s.		+12 18	− 91 32		
	−77 48	190 23	T.	−101 26	s.s.w.		+ 8 30	− 92 56		

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Feb. 9 P.M.	−77 57	188 30	R.	−102 30	S.S.W.		+ 8 52	− 93 38		
	−77 56	188 40	R.	−110 29	S.W. ½ S.		+14 32	− 95 57		
	−77 56	188 40	R.	−106 13	S.S.W. ¾ W.		+11 50	− 94 23		
	−77 54	188 36	R.	−105 51	S.W. by S.		+12 49	− 93 02		
	−77 54	188 36	S.	−103 13	S.S.W. ½ W.	−86 00	+10 50	− 92 23	− 93 41	
	−77 51	188 24	R.	−103 18	S.S.W. ½ W.		+10 50	− 92 28		
	−77 50	188 06	R.	− 94 04	S. ¼ W.		+ 1 04	− 93 00		
	−77 50	188 06	S.	− 94 38	S.		0 0	− 94 38		
10 A.M.	−77 35	187 59	S.	− 94 12	S.		0 0	− 94 12		
	−77 57	187 38	T.	−110 56	S.W. ½ W.		+17 38	− 93 18		
	−77 38	188 07	Y.	− 97 53	S. by W.		+ 4 28	− 93 25		
	−77 38	188 07	T.	−101 54	S.S.W.	−86 00	+ 8 52	− 93 02	− 93 41	
	−77 40	188 00	SM.	−108 00	S.W. by S.		+12 49	− 95 11		
	−77 48	188 00	S.	−108 49	S.W. by S.		+12 49	− 96 00		
	−77 48	188 00	O.	−105 38	S.W. ½ S.		+14 32	− 91 06		
	−77 48	188 04	T.	−106 04	S.W. by S.		+12 49	− 93 15		
11 A.M.	−76 45	189 06	O.	− 74 47	S. ¼ E.		− 1 06	− 75 53		
	−76 46	188 40	S	− 86 56	S. by W. ½ W.		+ 6 40	− 80 16		
	−76 46	188 40	S.	− 80 11	S.	−86 00	0 00	− 80 11	− 77 53	
	−76 46	188 40	S.	− 95 11	S.W. ½ S.		+14 32	− 80 39		
11 P.M.	−76 14	187 11	S.	− 86 06	N.W. ½ N.		+13 39	− 72 27		
14 A.M.	−76 23	178 25	S.	− 98 02	S. by W. ½ W.	−87 00	+ 8 50	− 89 12	− 85 10	
	−76 24	176 26	R.	− 91 24	S. by W. ¾ W.		+10 17	− 81 07		
15 P.M.	−76 03	168 56	R.	− 85 31	S. by E. ¼ E.		−10 13	− 95 44		
	−76 05	168 56	S.	− 88 32	S. by E. ½ E.	−87 50	−12 13	−100 45	− 98 45	
	−76 05	168 56	O.	− 86 55	S. by E. ½ E.		−12 13	− 99 08		
	−76 16	168 11	R.	− 85 10	S. by E. ¾ E.		−14 13	− 99 23		
16 A.M.	−76 20	165 33	S.	− 60 54	E. ½ N.		−45 47	−106 41		
	−76 20	165 33	T.	− 69 12	S.E. by E.		−37 32	−106 44		
	−76 20	165 33	O.	− 67 08	S.E. by E.	−87 53	−37 32	−104 40	−106 13	
	−76 20	165 33	Y.	− 65 20	E.S.E.		−42 18	−107 38		
	−76 20	165 33	T.	− 64 59	E.S.E.		−42 18	−107 17		
	−76 30	166 39	R.	− 58 06	E.		−46 13	−104 19		
16 P.M.	−76 35	166 17	R.	− 64 23	E. by S. ½ S.		−44 03	−108 26		
	−76 36	166 17	R.	−136 19	N.N.W. ½ W.		+19 46	−116 33		
	−76 36	166 17	Y.	−150 04	W.N.W.		+41 38	−108 26		
	−76 36	166 16	T.	−138 24	N.W. by N.		+23 31	−114 53		
	−76 36	166 16	Y.	−158 51	W.		+46 13	−112 38		
	−76 36	166 16	Y.	−156 58	W. by S. ½ S.		+44 03	−112 55		
	−76 36	166 16	T.	−156 05	S.W. ¼ W.	−87 53*	+33 04	−123 01	−113 23	
	−76 36	166 17	R.	−154 06	S.W. by W.		+37 32	−116 34		
	−76 36	166 17	R.	−142 54	S.W. ¼ S.		+29 45	−113 09		
	−76 37	166 16	R.	− 67 01	E.N.E.		−41 38	−108 39		
	−76 37	166 16	R.	− 67 53	E. by S.		−45 19	−111 51		
	−76 37	166 16	S.	− 66 32	E. by S.		−45 19	−113 12		
	−76 37	166 16	T.	− 73 45	E.S.E.		−42 18	−116 03		
	−76 37	166 35	R.	− 73 40	S.E. by E.		−37 32	−111 12		

* The inclination on the 16th of February is computed from the observed declinations with the head West — 158° 51′, and E. by S. — 67° 12′. From these we have the approximate inclination $\theta = -87^\circ\ 52'$. With this value of θ, $\psi' = -66^\circ\ 27'$ at East. Whence $\psi = -\dfrac{158^\circ\ 51' + 66^\circ\ 27'}{2} = -112^\circ\ 39'$; δ at East or West $= 46^\circ\ 12'$; and $\tan\theta = \dfrac{\sin 46^\circ\ 12'}{a} = \dfrac{\cdot 7218}{\cdot 0267} = -87^\circ\ 53'$.

Observations of Declination. (Continued.)

1841.	Position. Lat.	Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Feb. 17 A.M.	−76 44	165 48	S.	−122 02	S. by W.		+ 9 18	−112 44		
	−76 44	165 48	O.	−123 18	S. by W.		+ 9 18	−114 00		
	−76 44	165 48	Y.	−124 51	S. by W.		+ 9 18	−115 33		
17 P.M.	−76 27	164 18	R.	−113 59	S.	−88 05	0 00	−113 59	−113 41	
	−76 27	164 11	R.	−112 11	S.		0 00	−112 11		
	−76 26	164 02	R.	− 73 51	S.E. ½ E.		−38 49	−112 40		
	−76 26	164 02	T.	− 71 53	S.E. by E. ¼ E.		−43 52	−115 45		
	−76 26	164 02	R.	− 73 51	S.E. ½ E.		−38 49	−112 40		
18 A.M.	−76 16	165 53	T.	− 49 06	E. by S.		−51 20	−100 26		
	−76 16	165 53	T.	− 51 14	E. by S. ½ S.	−88 04*	−49 37	−100 51	− 99 41	
	−76 05	166 11	T.	− 71 05	N.E. by N.		−25 56	− 97 01		
18 P.M.	−76 06	166 11	T.	−152 46	W.		+52 20	−100 26		
	−76 03	166 23	S.	−142 55	W.N.W.		+46 47	− 96 08		
	−76 03	166 23	S.	−144 38	W. by N.		+51 20	− 93 18		
	−75 58	167 04	T.	− 71 05	N.E. by N.		−25 56	− 97 01		
	−75 58	167 04	T.	−149 32	W.	−88 04	+52 20	− 97 12	− 94 27	
	−75 49	167 32	R.	−134 35	S.W. by W.		+42 07	− 92 28		
	−75 45	167 32	R.	−132 32	S.W. by W.		+42 07	− 90 25		
	−75 42	167 30	S.	−135 47	S.W. by W.		+42 07	− 93 40		
	−75 42	167 30	R.	−133 08	S.W. ½ W.		+37 47	− 95 21		
19 P.M.	−74 46	167 53	R.	−110 59	S.W.	−88 02	+34 12	− 76 47	− 74 48	
	−74 46	167 53	T.	−107 01	S.W.		+34 12	− 72 49		
22 P.M.	−70 27	166 40	R.	− 18 35	E. by S. ¼ S.		−20 57	− 39 32		
	−70 27	166 40	T.	− 16 21	E. by N. ½ N.		−20 13	− 36 34		
24 A.M.	−70 14	168 13	Y.	− 50 20	N.W. ½ N.		+13 03	− 37 17		
	−70 14	168 13	T.	− 49 18	N.W. ½ N.	−85 50	+13 03	− 36 15	− 39 45	
24 P.M.	−70 24	167 20	S.	− 41 55	S. ½ E.		− 2 08	− 44 03		
	−70 26	167 19	R.	− 42 49	S.		0 00	− 42 49		
	−70 26	167 19	O.	− 41 44	S.		0 00	− 41 44		
25 P.M.	−70 07	167 27	R.	− 40 24	S. ½ W.		+ 2 08	− 38 16		
	−70 07	167 27	T.	− 40 16	S. ½ W.		+ 2 08	− 38 08		
	−70 06	167 29	R.	− 41 14	S.		0 00	− 41 14		
	−70 06	167 29	R.	− 44 06	N. by W. ¾ W.		+ 6 52	− 37 14		
	−70 04	167 32	T.	− 49 16	N.N.W.	−85 50	+ 7 50	− 41 26	− 39 21	
	−70 04	167 32	T.	− 56 14	N.W. by W. ½ W.		+18 27	− 37 47		
	−70 02	167 35	R.	− 52 55	N.W. by W.		+17 24	− 35 31		
	−70 02	167 11	S.	− 42 51	S. by W.		+ 4 17	− 38 34		
	−70 03	167 26	R.	− 46 21	S. by W.		+ 4 17	− 42 04		
26 A.M.	−69 54	167 56	S.	− 61 35	S.W. by W.		+18 16	− 43 19		
27 P.M.	−69 17	168 00	R.	− 48 44	N.W.		+13 27	− 35 17		
	−69 17	168 00	O.	− 50 39	N.W. ½ W.	−85 28	+15 12	− 35 27		
	−69 16	167 49	S.	− 45 13	S. by W.		+ 3 58	− 41 15		
	−69 25	167 39	R.	− 40 39	S. by W.		+ 3 58	− 36 41		
28 A.M.	−69 40	167 14	Sm.	− 34 21	S. by E.		− 4 12	− 38 33		
	−69 40	167 14	T.	− 35 28	S. by E. ½ E.		− 6 18	− 41 46	− 38 21	
	−69 40	167 25	T.	− 35 17	S. by E. ½ E.		− 6 18	− 41 35		
	−69 40	167 25	O.	− 36 51	S. by E.	−85 45	− 4 12	− 41 03		
	−69 40	167 27	S.	− 37 06	S. ½ E.		− 2 05	− 39 11		
28 P.M.	−69 47	167 13	R.	− 56 47	W.N.W.		+19 07	− 37 40		
	−69 36	167 14	R.	− 50 21	N.W. by W.		+17 02	− 33 19		

* The inclination is computed from the observed declination at West — 152° 46′, and at E. by S. — 49° 06′; with the approximate inclination which these give we have ψ' at East — 48° 06′; $\psi = -\frac{152^\circ\ 46' + 48^\circ\ 06'}{2} = -100^\circ\ 26'$; δ at East and West 52° 20′; and $\theta = -\frac{\sin 52^\circ\ 20'}{\cdot 0267} = -88^\circ\ 04'$.

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Mar. 1 A.M.	−69 22	167 40	S.	−47 21	N.W.		+12 31	−34 50		
1 P.M.	−68 51	167 47	R.	−48 53	N.W.byW.½W.		+15 45	−33 08		
	−68 56	167 49	O.	−33 25	S.		0 00	−33 25		
	−68 56	167 49	S.	−33 40	S. ½ E.		− 1 52	−35 32		
	−68 56	167 49	W.	−35 23	S. ½ E.		− 1 52	−37 15		
	−68 55	167 46	S.	−36 27	S. ½ E.	−85 10	− 1 52	−37 19	−36 12	
	−68 55	167 46	T.	−31 54	S. by E.		− 3 45	−35 39		
	−68 55	167 49	R.	−30 30	S.S.E.		− 7 22	−37 52		
	−68 55	167 49	T.	−32 46	S. ½ E.		− 1 52	−34 38		
	−68 57	167 46	R.	−30 24	S. by E. ½ E.		− 5 33	−35 57		
	−69 02	167 42	R.	−30 30	S.E. by S.		−10 40	−41 10		
	−69 03	167 41	R.	−56 02	W. ½ S.		+18 19	−37 43		
2 P.M.	−68 13	167 56	R.	−49 58	W. by N.		+15 07	−34 51		
	−68 12	167 53	T.	−50 32	W. ½ S.		+15 38	−34 54		
	−68 12	167 53	W.	−48 26	W. ¼ N.	−84 20	+15 30	−32 56		
	−68 12	167 53	T.	−46 36	W. ¼ N.		+15 30	−31 06	−32 35	
	−68 09	167 45	R.	−45 44	W. ½ N.		+15 22	−30 22		
3 A.M.	−67 40	167 40	T.	−48 33	W. ½ S.		+15 20	−33 13		
3 P.M.	−67 24	166 34	R.	−47 00	W. by S. ½ S.	−84 15	+14 52	−32 08		
	−67 23	166 33	S.	−46 12	W. by S.		+15 15	−30 57		
5 P.M.	−65 30	167 34	R.	−32 28	S.W. ½ S.		+ 9 23	−23 05		
6 A.M.	−65 40	165 06	T.	−36 36	S.S.W. ½ W.		+ 7 00	−29 36		
	−65 42	164 56	T.	−35 04	S.S.W.		+ 5 45	−29 19		
	−65 42	164 56	Sm.	−32 27	S.S.W. ½ W.		+ 7 00	−25 27		
	−65 42	164 56	O.	−30 51	S. by W.		+ 2 57	−27 54		
	−65 42	164 56	T.	−33 09	S. by W. ½ W.		+ 4 21	−28 48		
	−65 44	165 05	Y.	−35 17	S. by W. ½ W.	−83 45	+ 4 21	−30 56	−28 23	
	−65 44	165 05	S.	−38 41	S.W. ½ S.		+ 9 23	−29 18		
	−65 44	165 05	W.	−33 03	S.S.W. ½ W.		+ 7 00	−26 03		
	−65 44	165 05	W.	−37 39	S.W. by S.		+ 8 17	−29 22		
	−65 44	165 05	S.	−37 02	S.W. by S.		+ 8 17	−28 45		
	−65 50	164 41	R.	−35 55	S.S.W.		+ 5 45	−30 10		
	−65 50	164 42	R.	−38 38	S.W. by S.		+ 8 17	−30 21		
7 A.M.	−65 25	162 06	Y.	−32 12	N.W. ½ N.		+ 8 38	−23 34		
	−65 25	162 06	T.	−27 09	N. ¾ W.		+ 1 12	−25 57		
	−65 25	162 06	O.	−30 52	N. by W.	−83 50	+ 2 32	−28 20		
	−65 25	162 06	W.	−30 37	N.N.W. ½ W.		+ 6 22	−24 15		
	−65 25	162 06	T.	−30 50	N.N.W.		+ 5 09	−25 41	−25 54	
8 P.M.	−64 37	163 07	S.	−14 56	E. by N. ½ N.		−11 42	−26 38		
	−64 37	163 07	R.	−15 13	E. by N. ½ N.	−83 00	−11 42	−26 55		
9 P.M.	−64 32	163 59	R.	−34 46	S.W. by S.		+ 7 39	−27 07		
10 P.M.	−64 02	163 31	S.	−26 40	S. ¾ W.		+ 2 00	−24 40		
11 A.M.	−64 17	163 17	T.	−32 51	N.W.		+ 8 26	−24 25		
	−64 16	163 18	T.	−34 35	N.W. ½ W.		+ 9 12	−25 23		
	−64 16	163 18	Y.	−37 50	N.W. by W.		+ 9 59	−27 51		
	−64 16	163 18	W.	−35 16	N W. by W.		+ 9 59	−25 17		
	−64 16	163 18	Sm.	−36 46	W.N.W.		+11 17	−25 29		
	−64 16	163 19	T.	−36 10	W.N.W.	−83 00	+11 17	−24 53	−25 18	
11 P.M.	−64 02	163 06	S.	−32 38	S.W. by S.		+ 7 39	−24 59		
	−64 04	163 06	O.	−32 04	S.S.W. ½ W.		+ 6 25	−25 39		
	−64 04	163 02	T.	−33 33	S.W. by S.		+ 7 39	−25 54		
	−64 03	163 49	S.	−36 22	S.W. by W.		+10 53	−25 29		
	−64 03	162 45	W.	−34 23	S.W.byW.½W.		+11 25	−22 58		
12 A.M.	−63 57	161 11	T.	−28 07	S. by W.		+ 2 42	−25 25		
	−63 58	161 15	S.	−34 04	S.W. by S.		+ 7 39	−26 25		
12 P.M.	−64 07	161 16	T.	−35 27	W.N.W.	−83 00	+11 17	−24 10	−24 06	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declina-tion.	Remarks.
Mar. 12 P.M.	−64 07	161 16	W.	−35 19	W.N.W.	−83 00	+11 17	−24 02	−24 06	
	−64 07	161 16	R.	−36 25	W. by N. ½ N.		+11 42	−24 43		
	−64 07	161 16	T.	−36 17	W. ½ N.		+12 20	−23 57		
	−64 07	161 16	T.	−35 30	W. ½ S.		+12 30	−23 00		
	−64 06	161 10	R.	−35 11	W. by S.		+12 30	−22 41		
	−64 06	161 05	R.	−35 02	W. by S.		+12 30	−22 32		
14 P.M.	−62 48	157 14	R.	−18 31	S.E. by S.		− 7 07	−25 38		
	−62 48	157 14	O.	−21 04	S.S.E.		− 4 53	−25 57		
	−62 48	157 14	S.	−21 31	S.S.E.		− 4 53	−26 24		
	−62 50	157 14	R.	−19 00	S. by E. ½ E.	−82 33	− 3 43	−22 43		
	−62 50	157 14	R.	−12 11	S.E. by E.		−10 14	−22 35	−24 07	
	−62 50	157 14	Y.	−23 23	S.S.E.		− 4 53	−28 16		
	−62 55	157 02	W.	−22 29	S. by E.		− 2 32	−25 01		
17 A.M.	−64 19	153 40	T.	−28 35	S.W. by S.	−84 00	+ 8 39	−19 56		
	−64 19	153 40	W.	−29 15	S.W. by S.		+ 8 39	−20 36		
18 A.M.	−63 54	151 56	Sm.	− 6 11	E.N.E.		−13 28	−19 39		
	−63 54	151 52	S.	− 5 25	E.		−14 55	−20 20		
	−63 54	151 52	O.	− 7 29	S.E. by E.		−12 48	−20 17		
	−63 50	151 48	T.	− 7 33	S.E. by E.	−84 06	−12 48	−20 21	−20 15	
	−63 50	151 48	Sm.	− 7 15	S.E. by E.		−12 48	−20 03		
	−63 50	151 48	S.	− 8 05	S.E. by E.		−12 48	−20 53		
	−63 50	151 48	O.	− 8 21	S.E. by E. ½ E.		−13 16	−21 37		
	−63 50	151 48	R.	−18 02	S. by E.		− 3 00	−21 02		
	−63 50	151 48	T.	−19 05	S. by W.		+ 3 00	−16 05		
	−63 50	151 48	S.	−17 08	S.	−84 00	0 00	−17 08	−18 59	
	−63 50	151 48	R.	−14 09	S.S.E.		− 6 00	−20 09		
18 P.M.	−63 51	151 48	R.	−13 20	S. by E. ½ E.		− 4 30	−17 50		
19 A.M.	−64 14	149 10	T.	−27 16	S.W. by S.		+ 9 08	−18 08		
	−64 16	149 15	R.	−27 13	S.W. by S.		+ 9 08	−18 05		
	−64 16	149 15	W.	−26 08	S.W. by S.	−84 20	+ 9 08	−17 00	−16 41	
	−64 18	149 09	R.	−25 43	S.W. ½ S.		+10 20	−15 23		
19 P.M.	−64 24	148 27	R.	−26 04	S.W. by S.		+ 9 08	−16 56		
20 P.M.	−65 04	142 49	R.	−31 29	W.	−85 25	+19 26	−12 03	−12 37	
	−65 03	142 46	R.	−30 34	S.W. by W. ½ W.		+17 23	−13 11		
21 A.M.	−64 26	140 46	Sm.	−24 11	W.N.W.		+15 50	− 8 21		
	−64 26	140 46	Y.	−21 11	W.N.W.		+15 50	− 5 21		
	−64 26	140 46	Sm.	−22 47	W.N.W.		+15 50	− 6 57		
	−64 26	140 46	O.	−21 18	N.W. by W.	−84 55	+14 00	− 7 18	− 6 57	
	−64 18	140 27	S.	−19 40	N.W. by W.		+14 00	− 5 40		
21 P.M.	−64 01	140 31	W.	−23 56	W.N.W.		+15 50	− 8 06		
22 A.M.	−63 18	140 04	S.	− 3 46	N.		0 00	− 3 46		
	−63 18	140 04	O.	− 1 55	N. ½ E.		− 1 23	− 3 18		
	−63 18	140 04	T.	− 6 16	N. by W.		+ 2 44	− 3 32		
	−63 18	140 04	T.	−19 52	W. by N. ½ N.		+ 3 57	− 5 55		
	−63 18	140 04	Y.	−18 31	W.N.W.		+13 27	− 5 04		
	−63 20	139 52	S.	−20 19	W.N.W.		+13 27	− 6 52		
	−63 14	139 43	R.	−19 39	N.W. by W. ½ W.	−84 05	+12 37	− 7 02	− 5 58	
	−63 14	139 43	R.	−22 28	W.		+14 54	− 7 34		
	−63 09	139 28	R.	−21 01	W.N.W.		+13 27	− 7 34		
	−63 03	139 38	R.	−20 52	N.W. by W. ½ W.		+12 37	− 8 15		
	−63 03	139 38	R.	−14 41	N.W. ½ N.		+ 9 04	− 5 37		
	−63 03	139 38	R.	−22 01	W.		+14 54	− 7 07		
22 P.M.	−62 53	139 06	R.	−15 17	N.W. by W.		+11 39	− 3 38		
	−62 52	139 05	R.	−14 43	N.W. ¾ W.		+11 14	− 3 29		
	−62 32	137 40	R.	−20 26	W.	−84 00	+14 43	− 5 43	− 4 05	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
Mar. 22 P.M.	−62 32	137 40	R.	−16 55	W. by N. ½ N.	−84 00	+13 46	− 3 09	− 4 05	
	−62 28	137 26	R.	−18 35	W. by S. ½ S.		+14 17	− 4 18		
	−62 28	137 26	R.	−18 29	W. by N.		+14 15	− 4 14		
23 A.M.	−62 05	136 05	Sm.	−12 53	N.W. ½ W.		+10 18	− 2 35		
	−62 18	136 25	T.	−14 00	N.W. by W.		+11 08	− 2 52		
	−62 18	136 25	W.	−13 48	N.W. by W.		+11 08	− 2 40		
	−62 20	136 27	R.	−11 53	N.W. by W.	−83 45	+11 08	− 0 45	− 1 12	
	−62 17	136 29	R.	−11 41	N.W. by W.		+11 08	− 0 33		
	−62 16	136 26	R.	− 9 59	N.W. by W.		+11 08	+ 1 09		
	−62 13	136 20	R.	−11 19	N.W. by W.		+11 08	− 0 11		
23 P.M.	−62 07	136 08	R.	−11 05	N.W. by W. ½ W.		+11 27	+ 0 22		
	−62 07	136 08	R.	−14 02	W. ¼ S.		+13 32	− 0 30		
	−62 06	136 07	R.	−11 00	S.W. by W.	−83 30	+11 39	+ 0 39	− 0 27	
	−62 06	136 07	O.	−14 49	W. by N.		+13 07	− 1 42		
	−62 06	136 07	S.	−10 59	N.W. by W.		+10 42	− 0 17		
	−62 06	136 06	T.	−12 41	N.W. by W. ½ W.		+11 27	− 1 14		
25 A.M.	−60 30	131 47	S.	+ 0 15	N.W.		+ 8 40	+ 8 55		
	−60 30	131 47	O.	+ 1 13	N.W.		+ 8 40	+ 9 53		
	−60 30	131 47	Y.	+ 0 16	N.W.		+ 8 40	+ 8 56		
	−60 30	131 47	W.	+ 0 50	N.W.		+ 8 40	+ 9 31		
	−60 30	131 47	T.	− 0 35	N.W.		+ 8 40	+ 8 05		
	−60 23	131 28	R.	− 1 51	N.W. ½ W.	−83 10	+ 9 24	+ 7 33	+ 8 09	
	−60 23	131 28	R.	− 5 51	W.		+12 53	+ 7 02		
	−60 23	131 28	T.	− 3 10	N.W.		+ 8 40	+ 5 30		
	−60 23	131 28	W.	− 1 51	N.W.		+ 8 40	+ 6 49		
	−60 22	131 27	R.	+ 0 33	N.W.		+ 8 40	+ 9 13		
25 P.M.	−60 20	131 22	R.	+ 1 00	N.W. by N.		+ 6 44	+ 7 44		
	−60 20	131 22	T.	+18 20	E.N.E.		−11 17	+ 7 03		
	−60 20	131 22	T.	+18 12	E. ½ S.		−12 31	+ 5 41		
	−60 20	131 22	R.	+14 06	N.E. by N.	−83 00	− 6 44	+ 7 22	+ 7 38	
	−60 20	131 21	R.	+18 59	N.E. by E. ¾ E.		−10 57	+ 8 02		
	−60 20	131 21	Sm.	+19 01	E.N.E.		−11 17	+ 7 44		
	−60 20	131 21	R.	+22 22	E.		−12 33	+ 9 49		
	−60 20	131 21	Sm.	+17 35	N.E. by E.		− 9 59	+ 7 36		
	−60 20	131 21	T.	+18 36	E.N.E.		−11 17	+ 7 19		
	−60 20	131 21	S.	+18 17	N.E. by E.		− 9 59	+ 8 18		
	−60 20	131 21	W.	+20 05	E. ½ N.	−83 00	−12 20	+ 7 45	+ 8 18	
	−60 20	131 21	R.	+18 49	N.E. by E. ½ E.		−10 37	+ 8 12		
	−60 20	131 21	R.	+16 36	N.E.		− 8 26	+ 8 10		
	−60 19	131 21	R.	+ 3 47	N.W. by N.		+ 6 44	+10 31		
	−60 19	131 21	R.	+ 8 33	N.		0 00	+ 8 33		
26 A.M.	−59 25	130 14	R.	+ 3 21	N.W. by N.		+ 6 12	+ 9 33		
26 P.M.	−59 13	130 02	R.	+ 7 01	N.		0 00	+ 7 01		
	−59 13	130 02	S.	+ 4 42	N.N.W.		+ 4 10	+ 8 52		
	−59 11	130 00	R.	+ 1 49	N.N.W.	−82 36	+ 4 10	+ 5 59		
	−59 10	129 56	R.	+ 2 32	N.N.W.		+ 4 10	+ 6 42		
	−59 10	129 56	O.	+ 1 48	N.N.W.		+ 4 10	+ 5 58	+ 8 32	
	−59 10	129 56	W.	+ 2 48	N.N.W.		+ 4 10	+ 6 58		
	−59 03	129 40	S.	+ 4 59	N.N.W.		+ 4 10	+ 9 09		
27 A.M.	−58 08	128 46	R.	+ 8 55	N.N.W.		+ 3 54	+12 49		
	−58 08	128 46	S.	+ 5 44	N.N.W.	−82 00	+ 3 54	+ 9 38		
	−58 06	128 43	S.	+ 6 53	N.N.W.		+ 3 54	+10 47		
28 A.M.	−57 24	127 50	W.	− 2 21	W. ½ S.		+10 41	+ 8 20		
	−57 24	127 50	O.	+ 0 05	W. ½ S.	−81 45	+10 41	+10 46	+ 8 47	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
Mar. 28 A.M.	−57 19	127 49	R.	− 1 35	W. by S.	+81 45	+10 40	+ 9 05	+ 8 47	
	−57 19	127 49	T.	− 2 16	W. ½ S.		+10 41	+ 8 25		
	−57 20	127 47	R.	− 2 56	W.		+10 41	+ 7 45		
	−57 20	127 47	W.	− 1 20	W. ½ N.		+10 29	+ 9 09		
	−57 20	127 47	T.	− 3 05	W. by S. ¼ S.		+10 48	+ 7 43		
	−57 21	127 42	R.	− 2 05	W. ½ N.		+10 29	+ 8 24		
	−57 21	127 42	S.	− 3 34	W. ½ N.		+10 29	+ 6 55		
	−57 22	127 37	R.	+ 0 39	W.		+10 41	+11 20		
29 P.M.	−56 21	130 30	S.	+ 9 40	N.E.		− 6 27	+ 3 13		
	−56 21	130 42	R.	+13 12	N.E.		− 6 27	+ 6 45		
	−56 21	130 42	S.	+ 9 04	N.E.		− 6 27	+ 2 37		
	−56 16	130 46	R.	+13 24	N.E.		− 6 27	+ 6 37		
	−56 14	130 50	R.	+11 27	N.E.	−81 00	− 6 27	+ 5 00	+ 5 46	Very much motion; observations uncertain to two or three degrees.
	−56 05	130 42	T.	+14 07	N.E.		− 6 27	+ 7 40		
	−56 05	130 42	W.	+13 50	N.E. by N.		− 5 01	+ 8 49		
	−56 08	130 55	R.	+11 38	N.E.		− 6 27	+ 5 11		
30 A.M.	−55 20	131 39	Sm.	+ 8 57	N.E. ½ E.		− 6 33	+ 2 24		
	−55 00	131 43	T.	+ 6 27	N.E. by N.		− 4 38	+ 1 49		
	−55 00	131 43	Sm.	+ 5 43	N.E. by N.		− 4 38	+ 1 05		
	−55 00	131 43	S.	+ 6 27	N.E. by E.	−80 20	− 7 06	− 0 39	+ 1 34	
	−55 16	131 09	R.	+ 8 05	N.E. by E.		− 7 06	+ 0 59		
	−55 16	131 09	R.	+11 55	E.		− 8 59	+ 2 56		
	−55 14	131 12	R.	+ 8 55	N.E. ½ E.		− 6 33	+ 2 22		
	−55 14	131 12	T.	+ 6 27	N.E. ½ N.		− 5 17	+ 1 10		
	−55 14	131 12	S.	+ 4 16	N.E. by N.		− 4 38	− 0 22		
	−55 14	131 12	O.	+ 4 28	N.E. ½ N.		− 5 17	− 0 49		
	−55 14	131 18	Y.	+ 6 00	N.E. ½ E.	−80 20	− 6 33	− 0 33	+ 0 31	
	−55 14	131 18	W.	+ 5 28	N.E. by N.		− 4 38	+ 0 50		
	−55 11	131 15	R.	+ 6 33	N.E. by N.		− 4 38	+ 1 55		
	−55 11	131 15	T.	+ 6 04	N.E. by N.		− 4 38	+ 1 26		
30 P.M.	−55 05	132 48	W.	+ 3 18	N.E. ½ N.		− 5 05	− 1 47		
	−55 05	132 48	T.	+ 4 16	N.N.E.		− 3 00	+ 1 16		
	−55 05	132 48	S.	− 2 50	N.		0 00	− 2 50		
	−55 05	132 48	T.	+ 7 07	N.E. by N.		− 4 27	+ 2 40		
	−55 07	132 37	R.	+ 8 14	N.E. by N.	−80 00	− 4 27	+ 3 47	+ 1 05	
	−55 04	132 40	R.	+ 5 57	N.E. by N.		− 4 27	+ 1 30		
	−55 04	132 40	Y.	+ 8 43	N.E. by N.		− 4 27	+ 4 16		
	−55 02	132 42	R.	+ 4 56	N.E. by N.		− 4 27	+ 0 29		
	−55 02	132 42	T.	+ 4 55	N.E. by N.		− 4 27	+ 0 28		
31 A.M.	−54 07	134 31	S.	+ 4 23	N.E. by E.		− 6 29	− 2 06		
	−54 07	134 21	T.	+ 5 06	E.N.E.		− 7 26	− 2 14		
	−54 07	134 21	O.	+ 5 52	N.E. by E.		− 6 29	− 0 37		
	−54 01	134 35	T.	+ 5 57	E. by N.	−79 30	− 7 57	− 2 00	− 1 50	
	−54 01	134 35	S.	+ 6 33	E. ½ S.		− 8 16	− 1 43		
	−54 01	134 35	S.	+ 5 15	E. by N. ½ N.		− 7 38	− 2 23		
	−54 04	134 35	O.	+ 3 27	E.N.E.		− 7 26	− 3 53		
	−54 04	134 40	W.	+ 6 32	E.N.E.		− 7 26	− 0 48		
	−54 05	134 40	W.	+ 5 26	E. by N.		− 7 57	− 2 31		
	−54 04	134 43	R.	+ 6 25	E. by N. ½ N.	−79 30	− 7 38	− 1 13	− 1 44	
	−54 04	134 47	R.	+ 6 30	E. by N. ½ N.		− 7 38	− 1 08		
	−54 04	134 54	R.	+ 6 35	E. ½ N.		− 8 06	− 1 31		
	−54 04	134 54	R.	+ 7 04	E. ½ N.		− 8 06	− 1 02		
April 1 P.M.	−52 56	135 23	R.	+ 0 52	N.N.E.		− 2 42	− 1 50		
	−52 55	135 24	R.	+ 1 49	N.N.E.	−78 50	− 2 42	− 0 53	− 1 03	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Initials.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Mean Declination.	Remarks.
April 1 P.M.	−52° 55′	135° 24′	S.	+1° 34′	N.N.E.	−78° 50′	−2° 42′	−1° 08′	−1° 03′	
	−52 51	135 26	T.	+0 30	N.N.E.		−2 42	−2 12		
	−52 49	135 29	T.	+3 13	N.N.E.		−2 42	+0 31		
	−52 49	135 29	R.	+2 24	N.N.E.		−2 42	−0 18		
	−52 46	135 29	R.	+1 10	N.N.E.		−2 42	−1 32		
2 A.M.	−51 12	136 50	T.	−1 37	N.E. by N.		−3 30	−5 07		
	−51 12	136 55	R.	−1 00	N.N.E.		−2 28	−3 28		
	−51 12	136 55	S.	−5 26	N.	−77 40	0 00	−5 26	−4 39	
	−51 06	136 52	T.	−7 08	N. by W.		+1 12	−5 56		
2 P.M.	−51 07	136 59	R.	−0 49	N.N.E.		−2 28	−3 17		
5 P.M.	−44 52	143 30	S.	−0 06	N.E. by E.		−3 51	−3 57		
	−44 52	143 28	R.	−1 11	N.E. by E.	−73 20	−3 51	−5 02		
	−44 51	143 34	R.	−5 41	S.E. by S.		−3 17	−8 58		
6 A.M.	−44 09	145 33	T.	−6 33	E.		−4 38	−11 11		
	−44 09	145 35	R.	−5 35	N.E. by E. ½ E.		−3 42	−9 17	−8 46	
	−44 06	145 42	R.	−7 01	N.E. by E.		−3 26	−10 27		
	−44 05	145 43	T.	−7 19	N.E. by E.	−71 40	−3 26	−10 45		
	−44 01	145 53	T.	−6 50	N.E. by E.		−3 26	−10 16		
6 P.M.	−43 40	146 40	R.	−5 58	N.E. ½ E.		−3 08	−9 06		

Observations of the Inclination in H.M.S. Erebus, from September 1840 to April 1841, made with Needle R. F. 4.

Observers Captain Ross and Lieutenant Smith, R.N.

1840.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
	Magnetic Observatory, Van Diemen Island.									
Sept. 17.	−42 52	147 24	2 P.M.	Direct.	−71 06·8	Observed on shore.	......	−71 06	−70 38	
				S. at 20°.	−71 13·4					
				N. at 20°.	−71 12·1					
				S.	−71 15·1					
19.			11 A.M.	Direct.	−71 02·8					
28.			2 P.M.	Direct.	−71 05·7					
			3 P.M.	Direct.	−70 58·4					
29.			1 P.M.	Direct.	−71 05·2					
				S. at 20°.	−71 09·9					
			to	S. at 20°.	−71 07·2					
				N. at 20°.	−70 58·5					
			3 P.M.	Direct.	−71 02·6					
Oct. 17.	At anchor.		1 30 P.M.	Direct.	−70 39·1	S.E. by S.	−43	−71 24		
				S.	−70 42·8					
				Direct.	−71 46·7	W.	+24	−71 24		
				S.	−71 48·5					
			2 P.M.	Direct.	−70 29·9	S. by E.	−61	−71 33		
				S.	−70 33·4					
				Direct.	−70 35·6	S.S.E.	−53	−71 33		
				S.	−70 44·1					
21.			2 30 P.M.	Direct.	−71 00·5	S.E.	−32	−71 27		
				S.	−70 49·6					
			1 45 P.M.	Direct.	−72 06·7	W.N.W.	+46	−71 24		
				Direct.	−72 12·6					
29.			6 A.M.	Direct.	−72 20·9	N.	+74	−71 06		
				S.	−72 18·7					
				Direct.	−72 12·5	N.N.E.	+70	−71 00		
				S.	−72 07·8					
				Direct.	−72 10·3	N.E.	+64	−70 58		
				S.	−71 54·8					
				Direct.	−72 01·6	E.N.E.	+46	−71 15		
				S.	−71 59·6					
				Direct.	−71 22·5	E.	+24	−71 02		
				S.	−71 30·0					
				Direct.	−72 17·0	N.N.W.	+71	−71 12		
				S.	−72 29·4					
				Direct.	−72 37·8	N.W.	+64	−71 27		
				S.	−72 24·3				−70 45	
				Direct.	−71 21·0	W.S.W.	− 3	−71 26		
				S.	−71 24·5					
				Direct.	−71 38·0	W.	+24	−71 17		
				S.	−71 44·7					
				Direct.	−71 57·7	W.N.W.	+46	−71 00		
				S.	−71 34·9					
				Direct.	−70 52·0	S.W.	−32	−71 20		
				S.	−70 43·7					
				Direct.	−70 38·5	S.S.W.	−52	−71 27		
				S.	−70 32·3					
				Direct.	−70 16·9	S.	−61	−71 18		
				S.	−70 17·0					
				Direct.	−70 16·7	S.S.E.	−53	−71 09		
				S.	−70 16·2					

Observations of Inclination. (Continued.)

1840.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Oct. 29.	At anchor.		6 A.M.	Direct.	−70 46·5	S.E.	−31	−71 17	−70 45	
				S.	−70 44·6					
				Direct.	−71 12·8	E.S.E.	− 3	−71 16		
				S.	−71 12·8					
Nov. 13.	−44 16	149 29	1 15 P.M.	Direct.	−71 03·1	E.S.E.	− 3	−71 09	−70 41	
			to	S.	−71 05·8					
			2 15 P.M.	N.	−71 10·6					
14.	−45 13	151 57	10 40 A.M.	Direct.	−71 42·7	S.E.	−33	−72 17	−71 49	
			to	S.	−71 47·0					
			11 25 A.M.	N.	−71 43·5					
15.	−45 33	152 45	11 20 A.M.	Direct.	−72 26·0	E.	+23	−72 05	−71 37	
			to	S.	−72 18·3					
			Noon.	N.	−72 39·0					
16.	−46 18	154 30	1 30 P.M.	Direct.	−72 22·5	E.S.E.	− 5	−72 32	−72 04	
			to	S.	−72 21·2					
			2 20 P.M.	N.	−72 37·1					
17.	−47 46	157 40	10 45 A.M.	Direct.	−73 20·2	S.E. by E. ½ E.	−14	−73 42	−73 14	
			to	S.	−73 24·7					
			11 45 A.M.	N.	−73 37·7					
18.	−49 20	160 13	11 15 A.M.	Direct.	−74 22·7	S.E. by E. ½ E.	−15	−74 43	−74 15	
			to	S.	−74 41·0					
			Noon.	N.	−74 21·8					
19.	−50 28	164 9	11 20 A.M.	Direct.	−75 16·8	E.	+22	−74 51	−74 23	
			to	S.	−75 12·5					
			Noon.	N.	−75 11·0					
21.	Auckland Island.		1 15 P.M.	Direct.	−74 25·5	W.N.W.	+47	−73 49	−73 21	
	−50 33	166 19	to	S.	−74 19·5					
			4 P.M.	N.	−75 02·5					
				Direct.	−74 33·6	N.W. by W.	+59	−73 35	−73 07	
24.			11 30 A.M.	Direct.	−75 05·1	(Record omitted.)				
			to	S.	−75 03·6					
			0 30 P.M.	N.	−74 49·6					
	At the Magnetic Observatory.		2 00 P.M.	Direct.	−73 40·8	Observed on shore.	......	−73 41·3	−73 13·3	Mean of needles whose poles were inverted −73° 10′.
			to	S.	−73 39·8					
			5 30 P.M.	N.	−73 43·3					
26.	Pig Island.		9 00 A.M.	Direct.	−73 38·4	Observed on shore.	......	−73 36·3	−73 08·3	
			to	S.	−73 33·3					
	−50 32	166 12	10 00 A.M.	N.	−73 34·4					
				Direct.	−73 39·1					
	Shoe Island.		1 30 P.M.	Direct.	−77 27·5	Observed on shore.	......	−77 31	−77 03	Excessive local attraction.
			to	S.	−77 33·1					
			2 30 P.M.	N.	−77 31·3					
	200 yards west of the preceding station.		....	Direct.	−74 10·6	Observed on shore.	......	−74 11	−73 43	

Observations of Inclination. (Continued.)

1840.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Nov. 26.	At anchor.		6 00 to 6 40 P.M.	Direct.	−72 42·8	S.S.W.	−58	−73 43	−73 15	
				S.	−72 48·0					
			6 45 P.M.	Direct.	−73 40·4	W.S.W.	− 6	−73 43	−73 15	
				S.	−73 34·7					
30.	Auckland Island, Ocean Point.		7 45 A.M.	Direct.	−73 29·1	Observed on shore.	......	−73 28	−73 00	
				S.	−73 26·0					
	Sandy Bay.		2 00 P.M.	Direct.	−73 58·2		......	−73 54	−73 26	
				S.	−73 50·4					
	155 yards east of the preceding station.		2 30 P.M.	Direct.	−73 56·6		......	−73 54	−73 26	
				S.	−73 53·2					
				N.	−73 51·9					
Dec. 2.	Auckland Island.		1 20 P.M. to 2 30 P.M.	Direct.	−65 39·5	Observed on shore.	......	−65 30	−65 02	Excessive local attraction.
				S.	−65 28·0					
				N.	−65 13·0					
				Direct.	−65 38·0					
6.	At anchor.		7 15 A.M.	Direct.	−73 03.4	S.W.	−37	−73 41	−73 13	
				S.	−73 04·7					
			8 30 A.M.	Direct.	−72 46·5	S.S.W.	−59	−73 44	−73 16	
				S.	−72 44·6					
7.			11 00 A.M.	Direct.	−74 12·2	W. by S.	+ 8	−74 05	−73 37	
				S.	−74 13·6					
8			9 00 A.M.	Direct.	−72 30·5	S.	−67	−73 35	−73 07	
				S.	−72 25·1					
				Direct.	−72 33·0	S.S.E.	−59	−73 32	−73 04	
				S.	−72 32·5					
				Direct.	−73 10·2	S.E.	−37	−73 43	−73 15	
				S.	−73 01·8					
				Direct.	−73 27·5	E.S.E.	− 7	−73 37	−73 09	
				S.	−73 33·0					
				Direct.	−73 58·0	E.	+22	−73 32	−73 04	
				S.	−73 49·8					
				Direct.	−74 10·6	E.N.E.	+47	−73 25	−72 57	
				S.	−74 12·8					
				Direct.	−74 39·0	N.E.	+66	−73 35	−73 07	
				S.	−74 42·5					
				Direct.	−74 33·2	N.N.E.	+76	−73 21	−72 53	
				S.	−74 41·1					
				Direct.	−74 51·0	N.	+79	−73 33	−73 05	
				S.	−74 53·3					
				Direct.	−75 01·5	N.N.W.	+76	−73 46	−73 18	
				S.	−75 02·3					
				Direct.	−74 48·5	N.W.	+66	−73 38	−73 10	
				S.	−74 39·2					
				Direct.	−73 10·7	S.E.	−37	−73 48	−73 20	
12.				Direct.	−73 55·8	E. by N.	+36	−73 20	−72 52	
				Direct.	−73 37·4	E.	+22	−73 15	−72 47	
				Direct.	−74 30·0	N.E.	+66	−73 24	−72 56	
				Direct.	−74 09·4	N.E. by E.	+59	−73 10	−72 42	
				Direct.	−74 04·9	E.N.E.	+47	−73 18	−72 50	
				Direct.	−73 24·3	E. by S.	+ 7	−73 17	−72 49	
				Direct.	−73 21·3	E.S.E.	− 7	−73 28	−73 00	
				Direct.	−73 02·2	S.E. by E.	−22	−73 24	−72 56	

Observations of Inclination. (Continued.)

1840.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Dec. 14.	Campbell Island.		10 00 A.M.	Direct.	−75 42·8	N.W.	+67	−74 38	−74 10	
	−52 34	169 10		S.	−75 48·3					
	At anchor.		11 00 A.M.	Direct.	−74 53·7	W.	+22	−74 36	−74 08	
				S.	−75 02·4					
			1 00 P.M.	Direct.	−73 18·4	S.S.W.	−60	−74 16	−73 48	
				S.	−73 13·1					
			2 00 P.M.	Direct.	−73 44·5	Observed on shore.	......	−74 18	−73 50	Mean on shore −73 52·5. Mean on board −73 50.
			to	S.	−74 29·7					
			4 15 P.M.	N.	−74 27·8					
				Direct.	−74 30·2					
15.	At the Magnetic Observatory.		6 15 A.M.	Direct.	−74 24·5	Observed on shore.	......	−74 23	−73 55	
			to	S.	−74 24·4					
			8 30 A.M.	N.	−74 18·5					
				Direct.	−74 23·1					
16.	At Anchor.		1 00 P.M.	Direct.	−73 18·4	S.S.W.	−60	−74 16	−73 48	
				S.	−73 13·1					
17.	Running out of Harbour.		9 30 A.M.	Direct.	−73 42·1	E. by S.	+ 7	−73 35	−73 07	
				Direct.	−73 16·0	S.	−69	−74 25	−73 57	
18.	−53 47	169 02	4 30 A.M.	Direct.	−74 21·0	S.S.E.	−61	−75 28	−74 46	Uncertain. Very much motion.
				S.	−74 33·8					
	−54 25	169 16	5 00 P.M.	Direct.	−73 39·9	S.S.E. ½ E.	−57	−75 00		
				N.	−74 27·0					
19.	−55 50	170 6	10 15 A.M.	Direct.	−75 26·1	S. by W.	−71	−76 44	−76 16	
			to	N.	−75 40·5					
			11 10 A.M.	S.	−75 32·5					
21.	−57 15	170 40	4 20 A.M.	Direct.	−77 14·0	S.S.E.	−67	−78 11	−77 43	Ship pitching.
				N.	−77 01·2					
				N.S.	−76 58·0					
	−57 54	170 25	5 10 P.M.	Direct.	−77 15·0	S. by E.	−74	−78 19	−77 51	
			to	N.	−77 00·5					
			5 50 P.M.	N.S.	−77 00·1					
22.	−58 57	170 57	10 15 A.M.	Direct.	−77 24·2	S.	−77	−78 32	−78 04	
			to	S.	−77 19·0					
			11 10 A.M.	N.	−77 10·8					
				N.S.	−77 05·2					
23.	−59 41	169 38	10 15 A.M.	Direct.	−78 05·0	S.S.W.	−69	−79 14	−78 34	
			to	S.	−78 08·5			−79 17		
			11 20 A.M.	N.	−78 06·7			−79 16		
				N.S.	−77 59·0			−79 08		
	−59 48	169 42	6 40 P.M.	Direct.	−78 57·8	E.	+20	−78 38		
				N.S.	−78 59·0			−78 39		
24.	−60 14	170 15	5 00 A.M.	Direct.	−78 27·3	S.E. ½ S.	−52	−79 19	−78 53	
			to	N.	−78 13·4			−79 05		
			6 00 A.M.	N.S.	−78 24·0			−79 16		
			11 00 A.M.	Direct.	−78 05·5	S.S.E.	−70	−79 15		
			to	S.	−78 47·2			−79 57		
	−60 31	170 32	Noon.	N.	−78 13·6			−79 24		
				N.S.	−78 01·0			−79 11		

Observations of Inclination. (Continued.)

1840.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Dec. 24.	−60 46	170 44	5 15 P.M.	Direct.	−78 40·4	S.E. by S.	−59	−79 34	−79 06	
			to	S.	−78 37·5					
			6 10 P.M.	N.	−78 45·8					
				N.S.	−78 16·3					
25.	−61 34	170 40	2 15 A.M.	Direct.	−78 43·4	S.	−79	−79 58	−79 30	
			to	N.	−78 40·1					
			3 15 A.M.	N.S.	−78 32·9					
26.	−62 04	172 48	Noon.	Direct.	−81 29·2	N.	+88	−80 01	−79 41	
				?	−81 25·0			−79 57		
				?	−81 27·2			−79 59		
	−62 10	173 00	7 P.M.	Direct.	−79 28·3	S.S.W.	−71	−80 39		
27.	−62 40	173 40	10 30 A.M.	Direct.	−80 53·3	W. ½ N.	+27	−80 26	−79 58	
28.	−62 40	174 40	10 30 A.M.	Direct.	−79 26·4	S.	−80	−80 37	−80 09	
			to	S.	−79 21·4					
			11 45 A.M.	N.	−79 18·4					
				N.S.	−78 32·7					
	−62 52	174 28	3 00 P.M.	Direct.	−79 37·2					
				N.S.	−79 22·8					
29.	−64 00	172 44	8 40 A.M.	Direct.	−80 25·0	S.S.W. ½ W.	−67	−81 31	−81 03	
			to	S.	−80 24·1					
			10 20 A.M.	N.	−80 28·2					
				N.S.	−80 18·8					
	−64 06	172 38	10 30 A.M.	Direct.	−80 28·1	S.S.W.	−73	−81 41	−81 03	
			to	S.	−80 16·8			−81 30		
			11 45 A.M.	N.	−80 20·5	S. by W.	−80	−81 41		
				N.S.	−79 47·8			−81 08		
				Direct.	−80 17·3			−81 37		
30.	−64 30	172 51	6 45 A.M.	Direct.	−80 23·9	S.W. by S.	−61	−81 25	−81 11	
				N.S.	−80 16·2			−81 17		
	−64 31	173 00	10 45 A.M.	Direct.	−80 16·3	S.	−82	−81 38		
			to	S.	−80 14·4			−81 36		
			11 45 A.M.	N.	−80 17·9			−81 40		
				N.S.	−80 54·3			−82 16		
31.	−65 58	171 47	10 45 A.M.	Direct.	−81 23·8	S.	−84	−82 48	−82 20	
			to	S.	−81 25·6			−82 50		
			11 50 A.M.	N.	−81 29·3			−82 53		
				N.S.	−81 18·2			−82 42		
	−66 17	170 57	3 45 P.M.	Dircct.	−81 25·0	S. by W. ½ W.	−77	−82 42	−82 25	
			to	S.	−81 23·9			−82 41		
			4 40 P.M.	N.	−81 34·7			−82 52		
				N.S.	−81 49·4			−83 06		
1841. Jan. 1.	−66 30	169 13	10 00 A.M.	Direct.	−81 36·4	S.	−85	−83 08	−82 40	
				S.	−81 39·0					
				N.	−81 49·6					
				N.S.	−81 49·2					

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Jan. 1.	−66 32	169 45	11 25 A.M.	Direct.	−84 14·6	N.	+91	−82 59	−82 31*	
			to	S.	−84 31·7					
			0 30 P.M.	N.	−84 41·1					
				N.S.	−84 32·9					
2.	−66 23	170 12	10 40 A.M.	Direct.	−84 16·3	N.N.W. ½ W.	+82	−83 21	−82 53	
			to	S.	−85 01·6					
			11 45 A.M.	N.	−85 05·6					
				N.S.	−84 29·6					
3.	−65 39	170 44	11 00 A.M.	Direct.	−83 28·7	N.N.W.	+86	−82 19	−81 51	Much motion.
			to	S.	−83 46·0					
			Noon.	N.	−83 58·0					
				N.S.	−83 46·5					
4.	−65 22	172 40	10 15 A.M.	Direct.	−82 18·3	E. ½ S.	+ 9	−82 11	−81 43	Much motion.
			to	S.	−82 06·0					
			11 40 A.M.	N.	−82 19·0					
				N.S.	−82 39·1					
5.	−66 55	174 31	10 30 A.M.	Direct.	−82 03·7	S.E. by E.	−34	−82 38	−82 13	Sailing amongst loose ice.
				Direct.	−82 19·9	E.S.E.	−16	−82 36		
				Direct.	−82 06·1	S.E. ½ E.	−42	−82 48		
	−67 27	174 51	7 10 P.M.	Direct.	−83 03·6	E.S.E.	−16	−83 26	−82 58	Sailing in the pack.
			to	S.	−83 11·3					
			7 50 P.M.	N.	−83 09·2					
				N.S.	−83 15·5					
6.	−68 17	175 0	11 00 A.M.	Direct.	−83 40·0	E.S.E.	−17	−83 57	−83 12	Sailing in the pack.
				S.	−83 35·0	E.S.E.	−17	−83 52		
				Direct.	−82 23·1	S.E. by S.	−63	−83 26		
				Direct.	−82 35·4	S.E.	−50	−83 25		
				Direct.	−82 26·1	S.S.E.	−75	−83 41		
7.	−68 32	175 49	9 30 A.M.	Direct.	−84 04·4	E.	+18	−83 53	−83 28	Standing off and on in a pool of water in the pack. Smooth water.
			to	S.	−84 10·3					
			10 15 A.M.	N.	−84 19·6					
			to	Direct.	−84 10·8	W.	+18	−83 59		
			11 00 A.M.	S.	−84 18·1					
				N.	−84 22·3					
8.	−68 28	176 31	11 00 A.M.	Direct.	−83 35·2	W. by S. ½ S.	− 8	−83 43	−83 17	
			to	S.	−83 57·7			−84 06		
			Noon.	N.	−84 03·5	W.	+18	−83 46		
				N.S.	−84 03·2			−83 45		
				Direct.	−83 43·2			−83 25		
	On	ice.	1 20 P.M.	Direct.	−84 01·2	Observed on ice.	. . . . . .	−84 02·9	−83 34·9	The ice was slightly in motion.
	−68 28	176 32	to	S.	−84 06·8					
			2 00 P.M.	N.	−84 09·3					
				N.S.	−83 55·7					
			3 00 P.M.	Direct.	−84 01·5					

* The accordance of the results on the 1st of January with the ship's head on the north and south points, is extremely satisfactory with reference to the corrections, which on those points are very large and have opposite signs.

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Jan. 9.	−68 48	176 25	2 45 A.M.	Direct.	−82 41·8					
			to	S.	−82 41·4					
			4 00 A.M.	N.	−82 48·6	S.S.E.	−76	−84 08	−83 40	
				N.S.	−82 57·0					
	−69 15	176 14	11 40 A.M.	Direct.	−83 09·4					
10.	−70 23	174 50	10 35 A.M.	Direct.	−84 01·8					
			to	S.	−83 51·4	S.	−88	−85 28	−85 00	
				N.	−84 16·2					
			11 40 A.M.	N.S.	−83 52·5					
11.	−71 15	171 15	9 30 A.M.	Direct.	−84 48·4					
			to	S.	−84 48·5	S.	−89	−86 18	−85 50	
			11 00 A.M.	N.	−84 49·3					
				N.S.	−84 49·3					
	−71 24	170 44	4 40 P.M.	Direct.	−84 55·4					
			to	S.	−84 56·9	S. by W.	−86	−86 21	−85 53	
			5 50 P.M.	N.	−84 56·2					
				N.S.	−84 51·4					
12.	−71 47	170 52	10 46 A.M.	Direct.	−86 17·8					
			to	S.	−86 29·5	W.S.W.	−14	−86 38	−86 10	Much motion; observations indifferent.
			11 40 A.M.	N.	−86 25·2					
13.	−72 07	172 19	10 15 A.M.	Direct.	−87 14·7					
			to	S.	−87 44·5					
			11 40 A.M.	N.	−87 32·6	E. by N. ½ N.	+46	−86 41	−86 13	
				N.S.	−87 17·6					
14.	−71 51	172 40		Direct.	−87 04·5	E. by N. ½ N.	+46	−86 18	−85 53	Much motion.
15.	−71 54	171 37	9 00 A.M.	Direct.	−85 03·8	S.S.W.	−79	−86 23		
	−71 55	171 51	11 00 A.M.	Direct.	−86 43·2					
			to	S.	−87 10·4					
			Noon.	N.	−86 43·7	E.	+23	−86 23	−85 55	
				N.S.	−86 26·2					
16.	−72 12	172 13	9 15 A.M.	Direct.	−85 48·2					
			to	S.	−85 40·3					
			11 00 A.M.	N.	−85 48·5	S. by W.	−87	−87 09	−86 41	
				N.S.	−85 32·2					
17.	−72 09	173 35	7 30 A.M.	Direct.	−86 53·3					
			to	N.	−86 50·2	E.	+24	−86 31	−86 03	Much motion.
			8 30 A.M.	N.S.	−87 01·0					
18.	−72 57	176 06	11 00 A.M.	Direct.	−86 03·5	S.E. by E.	−33	−86 37		
				S.	−86 32·2			−87 05		
				N.	−86 32·3	E.S.E.	−14	−86 46	−86 11	
				N.S.	−86 04·0			−86 18		
				Direct.	−86 22·9	E. by S. ½ S.	− 4	−86 27		
19.	−72 35	173 34	10 00 A.M.	Direct.	−86 12·4					
			to	S.	−86 21·8					
			11 00 A.M.	N.	−86 22·2	S.W. by W.	−33	−87 04	−86 36	
				N.S.	−87 07·0					

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Jan. 19.	−72 31	173 39	4 30 P.M.	Direct.	−85 58·4					
			to	S.	−85 55·5	S. by E. ½ E.	−83	−87 19	−86 51	
			5 30 P.M.	N.	−86 04·1					
				N.S.	−85 45·8					
20.	−73 47	171 50	10 00 A.M.	Direct.	−86 56·7			−87 48		
			to	S.	−86 59·8	S.E.	−51	−87 51		
			11 15 A.M.	N.	−86 58·4			−87 49		
				N.S.	−86 59·1			−87 50	−87 04	
	−73 50	171 43	7 00 P.M.	Direct.	−86 49·0	S.W.	−51	−87 40		
			7 30 P.M.	Direct.	−86 04·7	S.W. by W.	−34	−86 39		
			7 50 P.M.	Direct.	−87 45·0	E. by N.	+39	−87 06		
21.	−74 10	170 28	0 30 A.M.	Direct.	−86 39·6			−88 07		
			to	S.	−86 37·4	S. by E.	−87	−88 04		
			1 30 A.M.	N.	−86 38·5			−88 06		
				N.S.	−86 30·5			−87 57	−87 12	
	−74 06	171 20	4 00 A.M.	Direct.	−87 48·1	E.	+24	−87 24		
	−74 00	170 43	10 40 A.M.	Direct.	−88 04·7	N.E. by E.	+66	−86 59		
			11 00 A.M.	Direct.	−88 46·3	N.E. by N.	+85	−87 21		
			11 40 A.M.	Direct.	−88 51·2	N.N.E.	+90	−87 21		
	−73 56	170 51	3 10 P.M.	Direct.	−88 40·4					
			to	S.	−88 57·1	N. by E.	+91	−87 22		
			4 20 P.M.	N.	−88 57·5					
				N.S.	−88 58·2					
22.	−73 56	172 20	11 25 A.M.	Direct.	−86 26·1				−87 11	
			to	S.	−86 32·3					
			0 15 P.M.	N.	−86 34·2	S. by E.	−87	−87 56	....	Very unsteady.
				N.S.	−86 21·7					
23.	−74 23	175 35	Noon.	Direct.	−86 59·0	E. by S.	+ 6	−86 53		
24.	−74 35	173 01	11 20 A.M.	Direct.	−86 36·8					
			to	N.	−86 23·0	S. by E.	−87	−87 59		
			11 50 A.M.	N.S.	−86 35·2				−87 29	
	−74 36	173 01	11 20 P.M.	Direct.	−86 49·9					
			to	S.	−86 41·4	S. ½ W.	−88	−88 16		
			0 20 A.M.	N.	−86 54·3					
25.	−74 38	170 09		N.S.	−86 39·7	S. ½ W.	−88	−88 08		
	−74 44	169 43	10 00 A.M.	Direct.	−88 12·4			−87 48		
			to	S.	−88 21·0	E.	+24	−87 57	−87 25	
			11 15 A.M.	N.	−88 17·0			−87 53		
				N.S.	−88 05·0			−87 41		
	−74 47	168 22	6 P.M.	Direct.	−87 24·7	S. by W. ½ W.	−85	−88 50		
				Direct.	−87 35·7	S.W. by S.	−68	−88 44	−88 18	
	−74 44	168 23	7 20 P.M.	Direct.	−87 34·0	S.S.W. ½ W.	−74	−88 48		
				Direct.	−87 49·2	S.W.	−52	−88 41		
26.	−74 54	169 00	5 45 A.M.	Direct.	−87 34·7	S. ½ E.	−89	−89 04		
			7 45 A.M.	Direct.	−87 46·4	S.W. by S.	−68	−88 54	−88 21	
	−74 58	169 02	8 20 A.M.	Direct.	−88 37·3	E. by S.	+ 7	−88 30		
27.	−75 22	168 48	2 20 A.M.	Direct.	−87 45·2					
			to	S.	−87 45·2	S.S.E.	−84	−89 04	−88 36	
			4 10 A.M.	N.	−87 45·6					
				N.S.	−87 23·3					

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Jan. 27.	−76 06	168 11	4 20 P.M.	Direct.	−88 05·4					
			to	S.	−88 06·1					
			5 20 P.M.	N.	−88 02·2	S.E.	−52	−88 55	−88 27	
				N.S.	−87 59·0					
28.	−76 46	169 22	11 15 A.M.	Direct.	−88 39·6	E.S.E.	−12	−88 52	−88 00	
	−77 29	170 30	7 00 P.M.	Direct.	−89 32·4	N.W. by N.	+85	−88 05		
29.	−77 47	175 43	6 00 A.M.	Direct.	−88 44·7					
				S.	−88 54·6	N. by W.	+91	−87 16	−86 48	
				N.	−88 50·2					
				N.S.	−88 36·7					
30.	−77 47	180 28	3 10 A.M.	Direct.	−87 51·4	N.N.W.	+88	−86 23	−85 54	Much motion.
	−77 35	181 20	Noon.	Direct.	−87 43·9	N.W. by N.	+83	−86 21		
31.	−77 04	188 18	9 30 A.M.	Direct.	−87 30·3			−86 07		
			to	S.	−87 36·4			−86 13		
	−77 06	189 06	11 30 A.M.	N.	−87 26·0	N.E. by N.	+83	−86 03	−85 56	
				N.S.	−88 07·6			−86 45		
	−77 12	190 54	7 00 P.M.	Direct.	−85 28·8	S. by E. ¼ E.	−82	−86 51		
Feb. 1.	−77 04	188 30	10 30 A.M.	Direct.	−85 45·9			−86 37		
			to	S.	−85 56·7	S.E.	−51	−86 48		
			11 30 A.M.	N.	−85 52·5			−86 43	−86 12	
				N.S.	−85 47·4			−86 38		
	−77 11	189 01	7 45 A.M.	Direct.	−86 02·5	S.W. by W.	−33	−86 36		
	−77 9	188 15	5 10 P.M.	Direct.	−85 59·2					
			to	N.	−85 52·4	S.E. by S.	−66	−86 51	−86 23	
			8 15 P.M.	N.S.	−85 36·3					
				Direct.	−85 30·9					
2.	−77 45	187 00	11 35 A.M.	Direct.	−86 27·2	E.	+23	−86 04		
			to	Direct.	−85 46·9	S.E.	−51	−86 38		
			Noon.	Direct.	−85 37·5	S.E. by S.	−66	−86 43	−86 10	
	−77 56	186 35	10 P.M.	Direct.	−85 43·0	S.W. by S.	−66	−86 49		
			10 30 P.M.	Direct.	−85 34·4	S. by W. ½ W.	−83	−86 57		
3.	−77 17	185 26	10 00 A.M.	Direct.	−86 57·4					
			to	S.	−87 02·3	W.S.W.	−14	−87 17	−86 49	
			11 15 A.M.	N.	−87 04·4					
				N.S.	−87 07·0					
4.	−77 00	192 18	9 30 A.M.	Direct.	−86 52·8	E.N.E.	+53	−86 00		
				Direct.	−86 43·5			−86 04		
				S.	−86 30·3	E. by N.	+39	−85 51	−85 36	
				N.	−86 35·3			−85 56		
				?	−85 03·8	S. by E.	−86	−86 30		
	−77 06	192 34	2 00 P.M.	Direct.	−86 29·5					
			to	Direct.	−86 50·6	E.N.E.	+52	−85 54	−85 26	
	−77 08	192 19	4 00 P.M.	S.	−86 49·0					
				N.	−86 54·0					
5.	−77 24	192 56	3 00 A.M.	Direct.	−86 27·2					
			to	S.	−86 36·0					
			4 00 A.M.	N.	−86 34·7	E.	+23	−86 13	−85 45	
				N.S.	−86 46·5					

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Feb. 5.	−77 10	192 48	11 45 A.M.	Direct.	−85 00·4	S.	−89	−86 34	−86 06	
			2 30 P.M. to 4 00 P.M.	Direct.	−84 57·2					
				S.	−84 53·1					
				N.	−85 26·3					
				N.S.	−85 09·9					
6.	−77 9	188 50	9 00 A.M. to 10 45 A.M.	Direct.	−86 52·2	E.N.E.	+53	−85 59	−85 54	
				S.	−87 03·0			−86 10		
				N.	−87 14·4			−86 21		
				N.S.	−87 29·8			−86 37		
				Direct.	−85 03·5	S.	−89	−86 33		
	−77 12	188 08	10 55 A.M.	Direct.	−85 12·1	S.S.W.	−79	−86 31		
7.	−76 58	186 40	6 00 A.M. to 7 15 A.M.	Direct.	−85 27·6	S. by W.	−86	−86 54	−86 23	
				S.	−85 38·6			−87 05		
				N.	−85 35·8			−87 02		
				N.S.	−85 29·3			−86 55		
	−77 01	186 35	11 30 A.M.	Direct.	−86 05·1	E.S.E.	−14	−86 19		
8.	−77 40	187 05	11 40 A.M.	Direct.	−87 02·5	E.N.E.	+53	−86 10	−85 51	
			1 30 P.M. to 3 45 P.M.	Direct.	−87 10·6	N.E. by E. ½ E.	+59	−86 12		
				S.	−87 04·5			−86 06		
	−77 47	187 18		N.	−87 29·6			−86 31		
				N.S.	−87 35·1			−86 36		
9.	−77 54	190 10	10 35 A.M.	Direct.	−87 16·3	N.E.	+75	−86 01	−85 49	
	−77 56	187 59	0 20 P.M.	Direct.	−85 27·9	S.E. by S.	−66	−86 34		
10.	−77 39	187 06	5 45 A.M. to 8 00 A.M.	Direct.	−85 15·1	S. by E.	−86	−86 41	−86 19	
				S.	−85 26·8			−86 53		
				N.	−85 34·4			−87 00		
				N.S.	−85 24·6			−86 50		
	−77 32	186 38	11 40 A.M.	Direct.	−86 33·7	W. by S.	+ 5	−86 29		
11.	−76 55	188 40	2 50 A.M.	Direct.	−87 16·6	N.W.	+75	−86 02	−86 07	
	−76 11	187 53	11 40 A.M.	Direct.	−85 55·0	S.W.	−51	−86 46		
			1 00 P.M.	Direct.	−85 29·3	S.S.W. ½ W.	−73	−86 42		
				S.	−85 39·4			−86 52		
12.	−76 50	183 26	10 15 A.M. to 11 40 A.M.	Direct.	−86 04·0	S.E. by E.	−33	−86 51	−86 23	Much motion.
				N.	−86 39·8					
				N.S.	−86 09·0					
14.	−76 16	174 14	3 A.M.	Direct.	−86 15·5	S.S.W.	−79	−87 43	−87 15	
	−76 22	176 9	11 40 A.M.	Direct.	−86 20·8					
	−76 16	175 50	2 00 P.M.	Direct.	−86 23·3					
				S.	−86 23·6					
				N.	−86 30·7					
				N.S.	−86 30·3					
	−76 14	172 35	11 20 P.M.	Direct.	−86 34·0	S.	−90	−88 04	−87 36	
15.	−76 03	169 30	11 20 A.M. to Noon.	Direct.	−87 05·3	S.	−91	−88 36	−88 21	
				N.	−87 13·5			−88 44		
				N.S.	−87 03·1			−88 34		
	−76 03	167 58	4 40 P.M.	Direct.	−87 30·1	S.S.E.	−81	−88 51		
	−76 09	167 00	7 10 P.M.	Direct.	−87 35·3			−88 56		
	−76 10	166 50	9 00 P.M.	Direct.	−87 36·4			−88 57		
	−76 12	166 30	11 00 P.M.	Direct.	−87 42·0			−89 03		

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	′	° ′	
Feb. 16.	−76 20	165 32	6 00 A.M.	Direct.	−87 42·8	S.S.E.	−81	−89 04	−88 35	
			to	S.	−87 49·1			−89 10		
			8 00 A.M.	N.	−87 37·8			−88 59		
				N.S.	−87 37·3			−88 58		
17.	−76 46	165 2	3 20 A.M.	Direct.	−88 33·2	E.S.E.	−13	−88 46	−88 19	
			4 15 A.M.	Direct.	−87 51·2	S.S.W.	−81	−89 12		
	−76 31	165 04	11 45 A.M.	Direct.	−87 05·3	S.	−91	−88 36		
	−76 26	164 02	4 00 P.M.	Direct.	−87 13·3			−88 44		
			5 00 P.M.	Direct.	−89 34·3	N.E. by E. ½ E.	+58	−88 36		
18.	−76 05	166 11	11 40 A.M.	Direct.	−89 26·5	W.	+26	−89 00	−87 53	
	−75 49	167 32	8 15 P.M.	Direct.	−88 10·1			−87 44		
19.	−75 03	168 44	11 00 A.M.	Direct.	−87 21·0	S.W.	−52	−88 13		
			to	S.	−87 35·0			−88 27		
			Noon.	N.	−87 44·2			−88 36		
				N.S.	−87 15·9			−88 08		Much motion.
20.	−73 09	171 26	Noon.	Direct.	−87 02·5	S.W.	−51	−87 54	−86 23	
21.	−71 17	170 43	9 00 A.M.	Direct.	−86 01·8	S.W. by W. ½ W.	−27	−86 26		
			to	S.	−86 03·6			−86 28		
			10 15 A.M.	N.	−86 10·7			−86 35		
	−71 04	170 07	10 50 A.M.	Direct.	−86 31·9	W.	+24	−86 08	−85 53	
	−70 52	168 11	6 40 P.M.	Direct.	−86 15·4	W.S.W.	−14	−86 29		
	−70 48	167 52	8 15 P.M.	Direct.	−86 30·4	W. by S.	+ 5	−86 25		
22.	−70 41	167 20	6 40 A.M.	Direct.	−87 28·0	N.N.E.	+88	−86 19	−85 51	A great deal of motion.
			to	S.	−87 57·8					
			7 30 A.M.	N.	−87 51·4					
				N.S.	−87 51·3					
	−70 27	166 40	5 00 P.M.	Direct.	−87 02·2	E. by N.	+39	−86 23	−86 19	
23.	−70 18	167 28	11 40 A.M.	Direct.	−87 31·9	N.E. ½ E.	+70	−86 22		
24.	−70 14	167 34	10 00 A.M.	Direct.	−85 50·4	S.S.W. ½ W.	−73	−87 03		
			to	S.	−85 45·8			−86 59		
			11 50 A.M.	N.	−85 42·7			−86 56		
				N.S.	−85 50·0			−87 03		
25.	−70 14	167 16	6 30 A.M.	Direct.	−85 20·7	S.	−89	−86 50	−86 06	Much motion.
			to	S.	−85 04·7			−86 34		
			8 00 A.M.	N.	−84 49·2			−86 18		
	−70 02	167 35	5 00 P.M.	Direct.	−87 25·3	N.W.	+75	−86 10	−85 41	
26.	−69 52	168 09	11 30 A.M.	Direct.	−85 54·7	W.S.W.	−14	−86 09		
27.	−69 24	167 55	10 30 A.M.	Direct.	−85 13·1	S.E.	−51	−86 04	−85 28	
			to	N.	−85 18·8			−86 10		
			Noon.	N.S.	−85 03·9			−85 55		
				Direct.	−85 34·1	E.S.E.	−14	−85 48		
				Direct.	−86 56·0	N.W.	+75	−85 41		
28.	−69 40	167 48	6 00 A.M.	Direct.	−85 03·2	S. by E.	−86	−86 29	−85 54	
			to	N.	−85 20·6			−86 47		
			8 00 A.M.	N.S.	−84 47·6			−86 14		
	−69 56	167 36	Noon.	Direct.	−85 14·4	S. by E.	−86	−86 40		
				Direct.	−86 45·6	N.W. by W.	+64	−85 42		

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Mar. 1.	−69 04	167 41	11 30 A.M.	Direct.	−86 51·5			−85 48		
	−69 06	167 42	2 00 P.M.	Direct.	−86 28·5			−85 25		
			2 30 P.M.	N.	−87 40·5	N.W. by W.	+64	−86 37	−85 26	Much motion.
	−69 08	167 44	3 00 P.M.	N.S.	−87 07·0			−86 03		
			3 30 P.M.	Direct.	−86 49·5	N.W.	+74	−85 36		
2.	−68 28	168 10	9 30 A.M.	Direct.	−86 12·0			−85 34		
				S.	−86 12·1			−85 34		
				N.	−86 10·2	W. by N.	+38	−85 32	−85 07	
				N.S.	−86 32·4			−85 54		
			11 15 A.M.	Direct.	−86 24·0	N.W. by W.	+64	−85 20		
3.	−67 52	167 28	6 15 A.M.	Direct.	−85 01·8			−84 41		
				S.	−85 19·2			−84 58		
				N.	−85 38·5	W.	+21	−85 17	−84 28	
	−67 47	167 23	7 45 A.M.	N.S.	−85 32·1			−85 11		
	−67 32	167 02	11 45 A.M.	Direct.	−84 55·5			−84 35		
4.	−66 44	165 45	11 40 A.M.	Direct.	−85 00·5	N.E.	+72	−83 49		
5.	−65 31	167 42	10 30 A.M.	Direct.	−85 05·8			−83 35		
			11 10 A.M.	N.	−85 17·2	N.	+91	−83 46		
	−65 28	167 47	11 40 A.M.	N.S.	−85 08·8			−83 38	−83 35	A great deal of motion. Ship rolling deep.
6.	−65 46	165 04	7 00 A.M.	Direct.	−83 38·3	S.S.W. ½ W.	−69	−84 47		
	−65 51	164 45	11 40 A.M.	Direct.	−83 28·3	S.W. by S.	−63	−84 31		
	−65 53	164 38	5 10 P.M.	Direct.	−84 34·0	W.	+18	−84 16		
7.	−65 53	162 14	10 00 A.M.	Direct.	−85 17·3	N.W.	+72	−84 05		
			10 40 A.M.	S.	−85 39·2			−84 27	−83 51	
			11 20 A.M.	Direct.	−84 08·5	W.S.W.	−17	−84 25		
8.	−64 41	162 34	10 10 A.M.	Direct.	−84 33·7			−83 15		
				S.	−84 47·7			−83 29		
				N.	−84 52·0	N.E. by N.	+79	−83 33	−82 55	
				N.S.	−84 32·6			−83 14		
	−64 38	162 50	11 15 A.M.	Direct.	−84 26·5	N.E. ½ E.	+67	−83 20		
9.	−64 22	164 32	7 30 A.M.	Direct.	−84 04·5	N.N.E.	+86	−82 39	−82 54	Much motion on the 10th.
10.	−64 05	163 17		Direct.	−85 01·7	N.N.E.	+86	−83 36		
11.	−64 13	163 18	9 30 A.M.	Direct.	−84 55·3	N.W. by W.	+62	−83 53		
12.	−63 57	161 11	6 00 A.M.	Direct.	−83 06·5	S.S.W. ½ W.	−69	−84 16		
			6 30 A.M.	Direct.	−82 44·3			−84 06		
			to	S.	−82 47·6			−84 10		
			7 45 A.M.	N.	−82 59·7	S. by W.	−82	−84 22	−83 32	
				N.S.	−82 10·5			−83 33		Much motion.
13.	−63 28	159 35	11 40 A.M.	Direct.	−83 07·0	S.W. by W. ½ W.	−25	−83 32		
14.	−62 41	156 59	10 30 A.M.	Direct.	−83 09·0			−82 51		
			to	S.	−83 17·0			−82 59		
			11 10 A.M.	N.	−83 28·7	W.	+18	−83 11	−82 33	
				N.S.	−83 14·7			−82 57		
			11 20 A.M.	Direct.	−81 52·5	S.S.E.	−75	−83 08		
15.	−63 50	156 06	6 45 A.M.	Direct.	−82 38·0					
			to	S.	−82 42·3					
			7 40 A.M.	N.	−83 08·3	S. ½ W.	−85	−84 22	−83 54	
				?	−83 19·5					

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Mar. 16.	−64 11	154 40	11 45 A.M.	Direct.	−83 28·2	S.W. ½ S.	−57	−84 25	−84 06	
			1 00 to	Direct.	−83 15·0	S.W. by S.	−64	−84 19		
	−64 13	154 03	3 15 P.M.	S.	−83 52·8			−84 57		
	−64 13	154 03		N.	−83 37·0	S.W. by S.	−64	−84 41	−84 06	
				N.S.	−83 28·3			−84 32		
				Direct.	−83 23·0			−84 27		
17.	−64 20	153 02	10 15 A.M.	Direct.	−83 27·6	S.W. by S.	−64	−84 32	−84 14	
			to	S.	−83 48·1			−84 52		
			11 15 A.M.	N.	−83 40·9			−84 45		
				N.S.	−83 47·2			−84 51		
				Direct.	−83 40·7	S.W.	−50	−84 31		
18.	−63 54	151 56	5 45 A.M.	Direct.	−84 44·0	W. by N.	+37	−84 34	−84 06	A heavy head swell.
			to	N.	−85 14·5					
			7 00 A.M.	N.S.	−85 35·2					
19.	−64 18	149 09	11 40 A.M.	Direct.	−84 00·5	S.W. by S.	−64	−85 05	−84 48	
			1 40 P.M.	Direct.	−84 09·7			−85 14		
				S.	−84 26·3			−85 30		
	−64 26	148 20	3 00 P.M.	N.	−84 26·1	S.W. by S.	−64	−85 30	−85 03	
				N.S.	−84 49·0			−85 53		
				Direct.	−84 05·0			−85 09		
	−64 56	147 14	6 15 P.M.	Direct.	−84 15·0	S.S.W.	−76	−85 31		
20.	−65 15	144 53	7 40 A.M.	Direct.	−84 55·7	S.W.	−51	−85 47	−85 05	
			8 50 A.M.	Direct.	−85 25·8	W.S.W.	−15	−85 41		
	−65 12	144 07	10 00 A.M.	Direct.	−86 03·5	W.N.W.	+52	−85 12		
	−65 12	144 07	10 30 A.M.	Direct.	−84 54·3	S.W.	−51	−85 45	−85 10	
			11 20 A.M.	Direct.	−85 08·0	S.W. by W.	−33	−85 41		
	−65 10	143 21	11 40 A.M.	Direct.	−85 12·8	W.S.W.	−15	−85 28		
	−65 10	143 21	11 50 A.M.	S.	−85 45·0	W.S.W.	−15	−86 00	−85 16	
			to	N.	−85 48·3			−86 03		
			1 00 P.M.	N.S.	−85 56·7			−86 12		
				Direct.	−85 55·0	W.	+21	−85 34		
	−65 06	142 40	4 45 P.M.	Direct.	−85 46·5	W.	+21	−85 26		
			6 20 P.M.	Direct.	−85 44·9	W. by N.	+38	−85 07		
21.	−64 20	140 40	5 40 A.M.	Direct.	−85 45·8	W.N.W.	+52	−84 54	−84 36	
			to	S.	−85 53·4			−85 01		
			7 00 A.M.	N.	−85 59·0			−85 07		
				N.S.	−86 11·0			−85 19		
				Direct.	−85 51·7			−85 00		
	−64 08	140 14	11 30 A.M.	Direct.	−84 24·5*	N. ½ W.				
22.	−63 09	139 28	9 30 A.M.	Direct.	−85 54·5	N.W. by W.	+62	−85 14	−84 46	
			to	S.	−86 33·1					
			11 10 A.M.	N.	−86 57·1					
				N.S.	−86 25·7					
				Direct.	−86 02·0					

* There is an obvious error here in the degree recorded; it should be probably 86°. The observation is not employed.—E. S.

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
Mar. 22.				Direct.	−85 59·7	N.W. by W.	+62	−85 14	−84 46	
				Direct.	−86 02·0					
22.	−62 46	138 22	4 00 P.M.	Direct.	−85 48·8					
23.	−62 13	136 20	10 15 A.M.	Direct.	−85 37·9					
			to	S.	−85 58·0	N.W. by W.	+62	−84 48	−84 20	
			Noon.	N.	−85 51·5					
				N.S.	−86 10·9					
				Direct.	−85 32·5					
24.	−61 20	134 05	6 10 A.M.	Direct.	−85 19·1					
			to	S.	−85 17·7					
			7 00 A.M.	N.	−85 33·9	N.W. by W.	+62	−84 23	−83 55	
				N.S.	−85 46·2					
	−61 11	133 52	11 40 A.M.	Direct.	−85 07·5					
25.	−60 22	131 27	11 45 A.M.	Direct.	−85 05·5	N.W.	+72	−83 54		
	−60 19	131 20	3 15 P.M.	Direct.	−85 04·1			−83 45		
			to	S.	−85 20·6	N.W. by N.	+79	−84 02	−83 31	
			4 15 P.M.	N.	−85 21·4			−84 02		
				N.S.	−85 32·5			−84 13		
26.	−59 25	130 14	10 15 A.M.	Direct.	−84 29·0					
			to	S.	−84 49·0					
			11 40 A.M.	N.	−84 28·7	N.W. by N.	+79	−83 20	−82 52	
				N.S.	−84 56·2					
				Direct.	−84 33·5					
27.	−58 06	128 43	11 40 A.M.	Direct.	−84 03·0	N.N.W.	+86	−82 37	−82 09	
28.	−57 22	127 37	10 30 A.M.	Direct.	−82 37·7	W.	+18	−82 20	−81 43	Much motion.
			11 45 A.M.	Direct.	−82 51·0	E.N.E.	+49	−82 02		
29.	−56 28	129 57	11 30 A.M.	Direct.	−82 21·5	N.E.	+71	−81 11	−80 43	Ship very unsteady.
30.	−55 00	131 43	6 15 A.M.	Direct.	−81 28·5	N.E. by E.	+62	−80 27		
			to	S.	−81 14·1			−80 12		
			7 15 A.M.	N.	−82 29·2			−81 12	−80 15	Ship very unsteady.
				N.S.	−82 36·0	N.E. by N.	+77	−81 19		
	−55 11	132 10	11 45 A.M.	Direct.	−81 41·0			−80 24		
	−54 55	132 50	5 00 P.M.	Direct.	−81 26·5			−80 10		
				S.	−81 48·5	N.E. by N.	+77	−80 32		
				N.	−81 59·7			−80 43		
				S.	−81 54·7			−80 38	−80 07	
				N.	−81 55·9	N.E. by N.	+77	−80 39		
				N.S.	−82 05·5			−80 48		
31.	−54 4	134 54	11 40 A.M.	Direct.	−79 45·5	E. ½ N.	+27	−79 19		
			0 15 P.M.	Direct.	−80 25·0	E.	+19	−80 06		
			1 00 P.M.	Direct.	−80 00·0	E. ½ N.	+27	−79 33		
	−54 00	135 02	2 00 P.M.	Direct.	−81 21·3			−80 11		
			to	S.	−81 50·2			−80 40	−79 39	
			3 30 P.M.	N.	−81 46·4	N.W.	+70	−80 36		
				N.S.	−81 26·6			−80 17		
				Direct.	−81 22·7			−80 13		

Observations of Inclination. (Continued.)

1841.	Position. Lat.	Position. Long.	Time of day.	Method employed.	Observed Inclination. Face east.	Ship's head.	Correction for ship's attraction.	Mean Inclination. Face east.	True Inclination.	Remarks.
	° ′	° ′	h m		° ′		′	° ′	° ′	
April 1.	−53 13	135 18	9 00 A.M.	Direct.	−80 48·5					
			to	S.	−81 20·1					
			11 45 A.M.	N.	−81 08·2	N.N.E.	+82	−79 37	−79 09	
				N.S.	−80 46·3					
				Direct.	−80 51·2					
2.	−51 16	136 50	6 00 A.M.	Direct.	−79 55·8					
			to	S.	−79 49·5	N.N.E.	+82	−78 27	−77 59	
			7 15 A.M.	N.	−79 47·7					
				N.S.	−79 45·0					
3.	−48 56	138 34	11 45 A.M.	Direct.	−78 41·6					
			2 00 P.M.	Direct.	−78 50·3					
			to	N.	−79 09·4	N.N.E.	+81	−77 22	−76 54	Much sea.
	−48 24	138 32	4 00 P.M.	N.S.	−78 13·0					
4.	−46 55	139 55	7 20 to	Direct.	−77 05·5					
			8 20 A.M.	N.	−77 29·8	N.E.	+69	−76 10	−75 42	Heavy sea, ship rolling deep.
				N.S.	−77 20·7					
			10 30 A.M.	Direct.	−77 00·5					Instrument in wrong azimuth.
			to	N.	−77 39·8	N.E.				
			11 50 A.M.	N.S.	−77 37·9					
	−46 34	140 36	Noon.	S.	−77 37·5					
				N.	−77 33·2					
				N.S.	−77 49·1	N.E.				
				Direct.	−78 11·5					
	−46 29	140 40	0 40 to	Direct.	−77 23·0					
			1 30 P.M.	S.	−76 33·5	N.E.	+69	−75 47		Heavy sea.
				N.	−76 29·0					
				N.S.	−77 18·0				−75 12	
	−46 22	141 06	4 40 P.M.	Direct.	−76 48·5					
			to	S.	−76 29·7					Much motion.
			5 50 P.M.	N.	−76 10·2	N.E. by E.	+62	−75 33		
				N.S.	−76 50·6					
5.	−45 02	145 10	6 30 A.M.	Direct.	−76 04·0					
			to	S.	−75 02·2	N.E. by E.	+60	−74 20		
			8 30 A.M.	N.	−75 11·5					
				N.S.	−75 03·2					
	−44 52	143 27	11 40 A.M.	Direct.	−75 49·5				−73 54	
			4 30 P.M.	Direct.	−75 28·5					
			to	S.	−74 57·6	N.E by E.	+60	−74 24		
			5 00 P.M.	N.	−75 20·9					
6.	−44 00	145 57	11 35 A.M.	Direct.	−73 49·8	N.E. by E.	+58	−72 52		
			1 20 P.M.	Direct.	−73 35·5			−72 34		
	−43 41	146 03	to	S.	−73 43·0	N.E. ½ E.	+62	−72 41	−72 15	Running along the land.
			4 30 P.M.	N.	−73 41·9			−72 40		
				N.S.	−73 47·6			−72 46		

Observations of the Intensity of the Magnetic Force made in Her Majesty's Ship Erebus, from September 1840 to April 1841, with Needle R. F. 4.

Observers Captain Ross and Lieutenant Smith, R.N.

1840.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
	° ′	° ′		° ′	°						
Sept. 17.	Magnetic Observatory, Hobarton.		Deflector S.	50 00·8	52						
	−42 52	147 24	wt. ½ gr.	2 41·4	52						
18.			wt. 1 gr.	5 22·7	52	Observed on shore*.	1·820	......	1·820		
			wt. 1½ gr.	8 14·6	52						
			wt. 2 grs.	10 49·6	52						
			wt. 3 grs.	16 15	52						
Oct. 17.		To obtain corrections for the ship's attraction.	S.	49 23	54	S.E. by S.	1·869	−·035	1·834		
			S.	49 51	54	W.	1·833	−·003	1·830		
			S.	49 27·2	54	S. by E.	1·864	−·043	1·821		
			S.	49 39	54	S.S.E.	1·849	−·039	1·810		
21.			S.	49 50·9	51	W.N.W.	1·833	+·008	1·841		
			S.	49 48·8	51	S.E.	1·835	−·031	1·804		
29.			S.	50 19·8	48	N.	1·792	+·028	1·820		
			S.	50 23·7	48	N.N.E.	1·787	+·024	1·811		
			S.	50 21·8	48	N.E.	1·789	+·020	1·809		
			S.	50 02·9	48	E.N.E.	1·816	+·008	1·824		
			S.	49 53·5	48	E.	1·828	−·003	1·825	1·823	
			S.	50 09·4	48	N.N.W.	1·807	+·024	1·831		
			S.	50 12·6	48	N.W.	1·803	+·020	1·823		
			S.	49 40	48	W.S.W.	1·848	−·017	1·831		
			S.	49 52·2	48	W.	1·831	−·003	1·828		
			S.	49 56·2	48	W.N.W.	1·826	+·008	1·834		
			S.	49 28·8	48	S.W.	1·862	−·031	1·831		
			S.	49 28·2	48	S.S.W.	1·863	−·039	1·824		
			S.	49 27·0	48	S.	1·864	−·046	1·818		
			S.	49 24·5	48	S.S.E.	1·867	−·039	1·828		
			S.	49 39·5	48	S.E.	1·849	−·031	1·818		
			S.	49 52·7	48	E.S.E.	1·830	−·017	1·813		
Nov. 13.	−44 10	149 29	S.	49 23·8	54	E.S.E.	1·868	−·017	1·851	1·844	
			N.	47 05·9	54		1·855	−·017	1·838		
14.	−45 13	151 57	S.	49 34·5	45	S.E.	1·855	−·031	1·824	1·833	Much motion. Observations by no means good.
			N	46 50·5	45		1·872	−·031	1·841		
15.	−45 33	152 45	S.	49 56·9	51	E.	1·824	−·003	1·821	1·843	Ship pitching greatly.
			N.	46 53·5	51		1·869	−·003	1·866		
16.	−46 18	154 30	S.	49 50·7	57	E.S.E.	1·833	−·017	1·816	1·820	
			N.	47 17	57		1·841	−·017	1·824		
17	−47 46	157 40	S.	49 52	51	S.E. by E. ½ E.	1·831	−·020	1·811	1·817	Much motion.
			N.	47 15	51		1·843	−·020	1·823		
18.	−49 20	160 13	S.	49 34	50		1·856	−·020	1·836	1·846	
			N.	46 47·2	50		1·876	−·020	1·856		

* The angles of deflection with 4, 5 and 6 grains, not having been observed at Hobarton, have been computed from the angles produced by the five weights which were employed at that station; they are as follows:—

gr.	° ′
4	22 06
5	28 03·5
6	34 21.

Observations of the Magnetic Force. (Continued.)

1840.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Nov. 19.	−50° 28′	164° 9′	S.	49° 11′	49°	E.	1·884	−·003	1·881	1·858	
			N.	47 20	49	E.	1·838	−·003	1·835		
21.	Auckland Island*. At anchor.		S.	49 44·2	42	W.N.W.	1·842	+·008	1·850	1·864	
	−50 33	166 19	N.	47 27·6	42	W.N.W.	1·830	+·008	1·838		
			wt. ½ gr.	2 33·9	42	W.N.W.	1·830				
			wt. 1 gr.	5 13	50	N.W. by W.	1·876	+·013	1·889		
			wt. 2 grs.	10 27·3	50	N.W. by W.	1·884	+·013	1·897		
			wt. 3 grs.	15 28·6	50	N.W. by W.	1·909	+·013	1·922		
26.			S.	49 29·2	41	S.S.W.	1·862	−·037	1·825		
27.			S.	49 50·6	42	W.S.W.	1·833	−·013	1·830		
24.	On shore.		S.	49 29	53	Observed on shore.	1·862	....	1·859		
			N.	46 50·2	53		1·873				
			wt. ½ gr.	2 33·5	52						
			wt. 1 gr.	5 18·4	52		1·844				
			wt. 1½ gr.	8 02·2	52		1·867				
			wt. 2 grs.	10 36·8	52		1·856				
			wt. 3 grs.	15 58·3	52		1·851				
26.	Pig Island.		S.	50 31	46		1·778	....	....		Excessive local attraction.
			N.	47 38	46		1·818				
	Shoe Island.		S.	47 50·7	44		1·981				
			N.	45 3·6	44		1·993				
30.	Ocean Point.		S.	49 49·8	51		1·834	....	1·847		
	Sandy Bay.		S.	49 28	51		1·863				
			S.	49 27	58		1·864				
			N.	47 31·7	58		1·826				
Dec. 2.	Auckland Island.		S.	59 56	55		....	....	....		Excessive local attraction.
			N.	57 19·2	55						
6.	At anchor.		S.	49 35	50	S.W.	1·854	−·030	1·824	1·836	
			S.	49 05·9	50	S.S.W.	1·891	−·036	1·855		
7.			S.	49 57·2	49	W. by S.	1·824	−·008	1·816		
8.			S.	49 21·9	52	S.	1·871	−·041	1·830		
			S.	49 19	52	S.S.E.	1·874	−·036	1·838		
			S.	49 29·2	50	S.E.	1·862	−·030	1·832		
			S.	49 29·5	50	E.S.E.	1·862	−·015	1·847		
			S.	49 44·9	50	E.	1·841	−·003	1·838		
			S.	49 46·7	51	E.N.E.	1·838	+·008	1·846		
			S.	49 58	52	N.E.	1·823	+·018	1·841		
			S.	50 06·9	52	N.N.E.	1·810	+·021	1·831		
			S.	49 51·4	50	N.	1·832	+·026	1·858		
			S.	50 01·8	50	N.N.W.	1·817	+·021	1·838		
			S.	50 16·3	50	N.W.	1·797	+·018	1·815		
10.			S.	49 27·2	52	S.E.	1 864	−·030	1·834		

* Mean of the results at Auckland Island, omitting those which appear to have been affected by excessive local attraction:

November 21 and 26, on board	..	1·864	1·851.
November 24, on shore	..	1·859	
November 30, on shore	..	1·847	
December 6, 7 and 8, on board	..	1·836	

Observations of the Magnetic Force. (Continued.)

1840.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.	Remarks.
	° ′	° ′		° ′	°					
Dec. 14.	Campbell Island*, at anchor.		S.	50 01·4	50	N.W.	1·819	+·018	1·837	
16.			S.	49 39·2	50	W.	1·849	—·003	1·846	1·846
			S.	49 04·5	52	S.S.W.	1·893	—·037	1·856	
	On shore.		S.	49 20·5	55	Observed on shore.	1·873	....	1·909	
			N.	46 10·8	55		1·917			
			wt. ½ gr.	2 35·3	55					
			wt. 2 grs.	10 12·1	55		1·930			
			wt. 3 grs.	15 30·2	55		1·906			
15.	—52 42	169 10	wt. ½ gr.	2 32·9	52					
			wt. 1 gr.	4 59·2	52		1·963			
			wt. 2 grs.	10 12·6	52		1·929			
			wt. 3 grs.	15 30·2	52		1·906			
			S.	49 17	52		1·877			
			N.	46 45·7	53		1·878			
18.	—53 47	169 02	S.	49 13·6	44	S.S.E.	1·881	—·037	1·844	
	—54 25	169 16	N.	46 18·5	44	S.S.E. ½ E.	1·908	—·034	1·874	
19.	—55 50	170 6	N.	45 48	48	S. by W.	1·943	—·040	1·903	
			N.S.	22 39·5	48					
21.	—57 15	170 40	N.	45 42·7	38	S.S.E.	1·949	—·035	1·914	
			N.S.	22 26						
	—57 54	170 25	N.	45 44·5	42	S. by E.	1·948	—·037	1·911	
			N.S.	22 25·6						
22.	—58 57	170 57	S.	48 17·7	41	S.	1·951	—·040	1·911	1·920
			N.	45 25·2			1·969	—·040	1·929	
			N.S.	22 31·7						
23.	—59 41	169 38	S.	48 11·5	39	S.S.W.	1·959	—·031	1·928	1·936
			N.	45 20·2			1·975	—·031	1·944	
			N.S.	22 29·5						
	—59 48	169 42	N.S.	22 31·5	37	E.				
24.	—60 14	170 15	N.	45 16·9	36	S.E. ½ S.	1·978	—·027	1·951	
			N.S.	22 27	36					
	—60 31	170 32	S.	47 59·2	42	S.S.E.	1·972	—·029	1·943	1·951
			N.	45 08·1	41		1·988	—·029	1·959	
			N.S.	22 27	40					
	—60 46	170 44	S.	48 13·7	40	S.E. by S.	1·956	—·027	1·929	1·960
			N.	45 15·1	40		1·980	—·027	1·953	
			N.S.	22 29·3	39					
25.	—61 34	170 40	N.	45 08·4	35	S.	1·988	—·032	1·956	
			N.S.	22 27·6	35					
26.	—62 04	172 48	N.	45 00	46	N.	1·997	+·011	2·008	
			N.S.	22 15·7	45					
28.	—62 40	174 40	S.	47 33·2	34	S.	2·001	—·032	1·969	1·983
			N.	44 30·6	34		2·029	—·032	1·997	
	—62 52	174 28	N.S.	22 0·5	34					
			N.S.	22 15·2	34					
29.	—64 0	172 44	S.	47 53·9	33	S.S.W. ½ W.	1·978	—·026	1·952	1·976
			N.	44 34·2	33		2·026	—·026	2·000	
	—64 06	172 38	N.S.	22 11·7	33					
			S.	47 45	34	S.S.W.	1·988	—·028	1·960	1·973
			N.	44 42·3	34	S. by W.	2·016	—·030	1·986	
			N.S.	22 14·7						

* Mean of the results at Campbell Island :

December 14 and 15, on shore.. 1·909 }
December 14 and 16, on board.. 1·846 } 1·877.

Observations of the Magnetic Force. (Continued.)

1840.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Dec. 30.	−64° 30′	172° 51′	N.S.	22° 17′·6	33°	s. by w.					
			S.	47 17	44	s.	2·018	−·030	1·988	1·988	
	−64 31	173 00	N.	44 41·1			2·018	−·030	1·988		
			N.S.	21 26·7							
31.	−65 58	171 47	S.	46 58·5	34		2·039	−·028	2·011	1·995	
			N.	44 34			2·026	−·028	1·998		
			N.S.	21 36·2							
	−66 17	170 57	S.	47 29·5	35	s. by w. ½ w.	2·005	−·023	1·982		
			N.	44 47·1			2·012	−·023	1·989		
1841.			N.S.	21 52·3							
Jan. 1.	−66 30	169 13	S.	47 15·8	37	s.	2·020	−·027	1·993	2·008	
			N.	44 30·1			2·030	−·027	2·003		
			N.S.	21 43·5							
	−66 32	169 45	S.	47 13	35	N.	2·023	+·006	2·029		
			N.S.	22 05·4							
2.	−66 23	170 12	S.	47 51·5	36	N.N.W. ½ W.	1·981	+·004	1·985	2·018	
			N.	44 13·9			2·047	+·004	2·051		
			N.S.	21 56·1							
3.	−65 39	170 44	S.	47 01·6	35	N.N.W.	2·035	+·005	2·040	2·046	Much motion.
			N.	44 14·5	34		2·047	+·005	2·052		
			N.S.	22 37·5	33						
4.	−65 22	170 40	S.	47 00·5	34	E. ½ S.	2·037	−·013	2·024	2·025	Much motion.
			N.	44 20·5			2·040	−·013	2·027		
			N.S.	21 54·1							
5.	−66 55	174 31	S.	47 11·7	35	E.S.E.	2·024	−·015	2·009	2·009	Sailing among loose ice.
			N.	44 35·9			2·023	−·015	2·008		
			N.S.	21 55							
6.	−68 17	175 0	S.	47 26·1	34		2·009	−·015	1·994	2·011	Among ice.
7.	−68 32	175 49	S.	47 15·8		E.	2·020	−·012	2·008		Standing off and on in the pack.
			N.	44 27·9			2·032	−·012	2·020		
			S.	47 16·5	30	W.	2·019	−·012	2·007		
			N.	44 21·1			2·040	−·012	2·028		
8.	−68 28	176 31	S.	47 09·1	39	E. by N. ½ N.	2·027	−·002	2·025	2·032	
			N.	44 04·7			2·058	−·002	2·056		
			N.S.	21 55							
			S.	47 03·3	39	W. by S. ½ S.	2·034	−·013	2·021		
			N.	44 22·6		W.	2·038	−·011	2·027		
			N.S.	22 00·1							
	−68 28	176 32	S.	47 15·7	42	Observed on ice.	2·021		2.021	2·025	
			N.	44 17·1			2·044		2.044		
			N.S.	21 54·8							
			wt. ½ gr.	2 28	41						
			wt. 3 grs.	14 34·3			2·021		2·021		
			wt. 6 grs.	30 38·7			2·015		2·015		
9.	−68 48	176 45	S.	47 06		S.S.E.	2·030	−·021	2·009	2·016	
			N.	44 16			2·045	−·021	2·024		
			N.S.	21 48·2							
10.	−70 23	174 50	S.	46 58·9	32	S.	2·038	−·022	2·016	2·033	Very unsteady.
			N.	43 49·2	31		2·073	−·022	2·051		
			N.S.	22 10							
11.	−71 15	171 15	S.	46 47·5	30		2·050	−·022	2·028	2·030	Very unsteady.
			N.	44 07·3	30		2·054	−·022	2·032		
			N.S.	22 03·5							
	−71 24	170 44	S.	46 49·9	45	s. by w.	2·047	−·021	2·026	2·029	
			N.	44 08·6			2·053	−·021	2·032		
			N.S.	21 53·6	43						

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Jan. 12.	° ′ −71 47	° ′ 170 52	S.	° ′ 46 41·5	° 34	W.S.W.	2·057	−·011	2·046	2·056	
			N.	43 44·1	33		2·078	−·011	2·067		
13.	−72 07	172 19	S.	47 24·5	33	E. by N. ½ N.	2·011	−·005	2·006	2·038	Much motion. Observations indifferent.
			N.	43 47·4	33		2·075	−·005	2·070		
			N.S.	21 47·9	33						
15.	−71 55	171 51	S.	47 25·2	33	E.	2·010	−·007	2·003	2·028	
			N.S.	21 45·2							
			N.	44 02			2·060	−·007	2·053		
16.	−72 12	172 13	S.	46 52·4	28	S. by W.	2·044	−·019	2·025	2·032	
			N.	44 04			2·058	−·019	2·039		
			N.S.	21 47·5							
17.	−72 09	173 35	N.	44 26·7	30	E.	2·033	−·007	2·026		Much motion.
			N.S.	21 36·5							
18.	−72 57	176 06	S.	46 30·1	31	S.E. by E.	2·070	−·014	2·056	2·038	
			N.	44 28·7		E.S.E.	2·031	−·011	2·020		
			N.S.	22 01·5							
19.	−72 35	173 34	S.	46 49·8	41	S.W. by W.	2·047	−·015	2·032	2·035	
			N.	44 07·9			2·054	−·015	2·039		
			N.S.	21 54·8							
	−72 31	173 39	S.	46 53	34	S. by E. ½ E.	2·044	−·018	2·026	2·039	
			N.	43 51·8			2·070	−·018	2·052		
			N.S.	21 50·1							
20.	−73 47	171 50	S.	46 31·9	34	S.E.	2·067	−·014	2·053	2·052	
			N.	43 56·3			2·066	−·014	2·052		
			N.S.	21 37·7							
21.	−74 10	170 28	S.	46 50·7	30	S. by E.	2·046	−·019	2·027	2·044	
			N.	43 41·8			2·080	−·019	2·061		
			N.S.	21 39							
	−74 06	171 20	S.	46 42	31	N. by E.	2·056	−·004	2·052	2·052	
			N.	44 06			2·056	−·004	2·052		
			N.S.	22 08·6							
22.	−73 56	172 20	S.	46 57·7	32	S. by E.	2·041	−·017	2·024	2·035	Very unsteady.
			N.	44 00			2·062	−·017	2·045		
			N.S.	21 52·2							
24.	−74 35	173 01	N.	44 07	29		2·055	−·017	2·038	2·037	
			N.S.	21 27·8							
25.	−74 36	173 01	S.	46 51·7	29	S. ½ W.	2·045	−·018	2·027		
			N.	43 59			2·063	−·018	2·045		
25.	−74 44	169 43	N.S.	21 47							
			S.	46 48·6	30	E.	2·048	−·007	2·041	2·045	
			N.	44 05·7	30		2·056	−·007	2·049		
			N.S.	21 50·3	29						
27.	−75 22	168 48	S.	46 42	30	S.S.E.	2·056	−·016	2·040	2·048	
			N.	43 48·6	28		2·073	−·016	2·057		
			N.S.	22 01	27						
	−76 06	168 11	S.	47 01·2	33	S.E.	2·036	−·015	2·026	2·031	
			N.	44 07·3			2·055	−·015	2·040		
			N.S.	21 44·4							
28.	−76 46	169 22	S.	46 59·9	37	E.	2·037	−·008	2·029	2·040	Two points out of the meridian.
			N.	44 03·7	37		2·058	−·008	2·050		
			N.S.	22 0·0	37						
29.	−77 47	175 43	S.	47 19·9	29	N. by W.	2·015	−·005	2·015	2·017	
			N.	44 32·2	29		2·028	−·005	2·023		
			N.S.	21 51·9	28						

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Jan. 31.	−77° 04′	188° 18′	S.	47° 43·6′	25°	N.E. by N.	1·989	−·001	1·988	2·017	
			N.	44 23·5			2·036	−·001	2·035		
			N.S.	22 26·6							
Feb. 1.	−77 04	188 30	S.	47 06·9		S.E.	2·029	−·016	2·013		
			N.	44 13·5			2·047	−·016	2·031		
			N.S.	22 14·8							
	−77 09	188 15	wt. 6 grs.	30 45	30		2·014	......	....		Ship's motion very considerable.
			wt. 1 gr.	4 42	31						
			wt. ½ gr.	2 27·6	31						
3.	−77 17	185 26	S.	46 59·9	33	W.S.W.	2·037	−·012	2·025	2·023	
			N.	44 02·6	34		2·034	−·012	2·022		
			N.S.	21 55·6	35						
4.	−77 00	192 18	S.	46 57·2		E. by N.	2·040	−·006	2·034	2·039	
			N.	44 16·3	24		2·045	−·006	2·039		
			N.S.	22 00·1							
			S.	47 01·7	23		2·035	−·006	2·029		
			N.	44 00	21		2·062	−·006	2·056		
5.	−77 10	192 48	S.	46 57·8	24	E.	2·039	−·007	2·032	2·036	
			N.	44 14·2			2·047	−·007	2·040		
			N.S.	22 10	19	S.					
	−77 14	192 02	S.	46 41·5	20		2·056	−·021	2·035	2·020	
			N.	44 33	19		2·027	−·021	2·006		
			N.S.	22 07·8	18						
6.	−77 09	188 50	S.	47 07·7	28	E.N.E.	2·028	−·005	2·023	2·036	
			N.	44 06·6	24		2·055	−·005	2·050		
			N.S.	21 58·9							
7.	−76 58	180 40	S.	46 50·9	27	S. by W.	2·046	−·019	2·027	2·035	
			N.	44 00·4	24		2·062	−·019	2·043		
			N.S.	22 02·3	23						
8.	−77 47	187 18	S.	47 03	34	N.E. by E. ½ E.	2·034	−·004	2·030	2·035	
			N.	44 23·2	33		2·038	−·004	2·034		
			N.S.	22 03·4	32						
			wt. 6 grs.	30 30·9			2·023	−·004	2·019		
			wt. 3 grs.	14 14·6			2·071	−·004	2·067		
			wt. 2 grs.	9 15·6			2·124	−·004	2·120		
			wt. 1 gr.	6 15·1							
			wt. ½ gr.	2 27·8							
10.	−77 39	187 06	wt. 6 grs.	30 34·7	28	S. by E.	2·019	−·019	2·000		
			wt. 3 grs.	14 37			2·019	−·019	2·000		
			wt. 2 grs.	9 30·9			2·067	−·019	2·048		
			wt. 1 gr.	4 34·2							
			wt. ½ gr.	2 13·2							
			S.	46 55·5	33		2·041	−·019	2·022		
			N.	44 13·9	29		2·047	−·019	2·028		
			N.S.	21 55·9	29		2·041	−·019	2·022		
11.	−76 55	188 40	S.	46 47	21	N.W.	2·050	−·002	2·048		
12.	−76 50	183 26	N.	44 13·2	25	S.E. by E.	2·048	−·013	2·035		Much motion.
			N.S.	21 47·5	24						
14.	−76 16	175 50	S.	46 55·1	34	S.S.W.	2·042	−·017	2·025	2·017	
			N.	44 33·7	33		2·026	−·017	2·009		
			N.S.	22 09·9	32						
15.	−76 03	169 30	N.	44 08·5	30	S.	2·053	−·020	2·033	2·033	
			N.S.	22 00·2	30						
16.	−76 20	165 32	S.	46 45·9	30	S.S.E.	2·051	−·012	2·039	2·041	
			N.	44 08·4	30		2·054	−·012	2·042		
			N.S.	22 09·6	29						

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Feb. 19.	−75 03	168 44	S.	46 38·8	35	s.w.	2·059	−·011	2·048	2·040	
			N.	44 16·9	32		2·044	−·011	2·033		
			N.S.	22 03·2	31						
21.	−71 17	170 43	S.	46 55·7	32	s.w. by w. ½ w.	2·041	−·011	2·030	2·037	
			N.	44 07·7	30		2·055	−·011	2·044		
	−71 34	178 07	S.	47 04	27	w.	2·033	−·007	2·026	2·026	
			N.	44 28·2	26		2·032	−·007	2·025		
			N.S.	22 12	26						
22.	−70 41	167 26	S.	47 01·4	24	n.n.e.	2·036	−·001	2·035	2·036	Much motion.
			N.	43 48·5	24		2·073	−·001	2·072		
			N.S.	22 01·3	23						
24.	−70 14	167 34	S.	46 43·4	26	s.s.w. ½ w.	2·055	−·018	2·037		
			N.	44 09·6	25		2·052	−·018	2·034		
			N.S.	22 12·1	24						
25.	−70 14	167 16	N.	44 35·3	22	s.	2·024	−·020	2·004		Much motion.
			N.S.	21 41·1	19						
27.	−69 24	167 55	S.	46 46·5	30	s.e.	2·050	−·016	2·034	2·025	Unsteady.
			N.S.	21 59·9	29						
28.	−69 40	167 48	N.	44 27·1	22	s. by e.	2·033	−·019	2·014		
			N.S.	21 55·9	21						
Mar. 1.	−69 08	167 44	N.	44 31	24	n.w. by w.	2·029	−·002	2·027		
			N.S.	21 56	22						
2.	−68 28	168 10	S.	46 50·3	27	w. by n.	2·048	−·005	2·043	2·047	
			N.	44 07·8	26	n.w. by w.	2·054	−·002	2·052		
			N.S.	22 20	28						
3.	−67 52	167 28	S.	46 43·4	16	w.	2·055	−·007	2·048	2·043	
			N.	44 17·5	14		2·044	−·007	2·037		
			N.S.	22 27·9	14						
5.	−65 31	167 42	N.	44 25·1	28	n.	2·035	+·006	2·041		A good deal of motion.
			N.S.	22 23·2	27						
7.	−65 33	162 14	S.	47 31·7	34	n.w.	2·002	+·003	2·005	2·024	
8.	−64 41	162 34	S.	47 17·9	35	n.e. by n.	2·017	+·004	2·021		
			N.	44 19·6	33		2·041	+·004	2·045		
			N.S.	22 09·6	34						
11.	−64 13	163 18	S.	47 29·3	31	n.w. by w.	2·005	+·002	2·007	2·018	
			N.	44 33	30		2·027	+·002	2·029		
			N.S.	22 29·8	30						
12.	−63 57	161 11	S.	47 06·8	31	s. by w.	2·029	−·022	2·007	2·010	
			N.	44 25·4	30		2·035	−·022	2·013		
			N.S.	21 59	30						
14.	−62 41	156 59	S.	47 13	28	w.	2·023	−·012	2·011	2·022	
			N.	44 16·7	28		2·045	−·012	2·033		
			N.S.	21 49·7	28						
15.	−63 50	156 06	S.	47 02·7	33	s. ½ w.	2·034	−·024	2·010	2·013	
			N.	44 22·3	31		2·039	−·024	2·015		
			N.S.	21 40·8	31						
16.	−64 13	154 03	S.	47 04·3	22	s.w. by s.	2·033	−·020	2·013	2·011	
			N.	44 31	22		2·029	−·020	2·009		
			N.S.	22 10·1	22						
17.	−64 20	153 02	S.	46 50·1	26		2·047	−·020	2·027	2·032	
			N.	44 03·6	25		2·058	−·020	2·038		
			N.S.	22 09·2	25						
18.	−63 54	151 56	N.	44 32	29	w. by n.	2·028	−·005	2·023		A heavy head swell.
			N.S.	22 42	27						
19.	−64 26	148 20	S.	46 23·5	30	s.w. by s.	2·078	−·020	2·058	2·065	
			N.	43 29·9	29		2·092	−·020	2·072		
			N.S.	22 01	29						

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
Mar. 20.	−65° 10′	143° 21′	S.	46° 45′·7	22°		2·051	−·012	2·039		Along the edge of the pack.
			N.	43 54·1	21	W.S.W.	2·068	−·012	2·056		
			N.S.	22 16·5	21					2·068	
21.	−64 20	140 40	S.	45 55·9	22		2·106	−·004	2·102		
			N.	43 41	21	W.N.W.	2·081	−·004	2·077		
			N.S.	21 29·5	21						
22.	−63 09	139 28	wt. 5 grs.	25 11·2	34		2·012	−·002	2·010		
			wt. 4 grs.	19 34·1	34		2·045	−·002	2·043		
			wt. 3 grs.	14 18·6	34		2·062	−·002	2·060		
			wt. 3 grs.	14 13	34		2·074	−·002	2·072	2·043	
			wt. 2 grs.	9 39	34		2·040	−·002	2·040		
			S.	46 53·9	34		2·043	−·002	2·041		
			N.	44 21·6	34		2·039	−·002	2·037		
			N.S.	22 00·2	34	N.W. by W.					
23.	−62 13	136 20	S.	47 16·5	35		2·019	−·000	2·019		
			N.	44 14·5	34		2·046	−·000	2·046		
			N.S.	21 36·6						2·051	
24.	−61 20	134 05	S.	46 47·2	35		2·050	−·000	2·050		
			N.	43 50·1	35		2·072	−·000	2·072		
			N.S.	21 56	35						
25.	−60 19	131 20	S.	46 41·1	38		2·057	+·003	2·060	2·071	
			N.	43 42·6	37	N.W. by N.	2·079	+·003	2·081		
			N.S.	21 58	36						
27.	−58 00	128 40	S.	46 59·2	35		2·038	+·005	2·043	2·056	
			N.	43 58	34	N.N.W.	2·064	+·005	2·069		
			N.S.	22 01·1	34						
30.	−55 00	131 43	S.	47 34·3	40	N.E. by E.	2·000	+·003	2·003		Very unsteady.
			N.	44 26·7	38		2·033	+·007	2·040		
			N.S.	22 20·5	38						
	−54 58	132 50	S.	47 30	40		2·004	+·007	2·011		Deflecting needle had a fall; repeated the observations to find if any effect was produced.
			N.	44 43·5	40	N.E. by N.	2·016	+·007	2·023	2·027	
			S.	47 31·7	39		2·002	+·007	2·009		
			N.	44 44·4	39		2·016	+·007	2·023		
			N.S.	22 33·8	39						
31.	−54 00	132 02	S.	46 56·3	40		2·041	+·006	2·047		
			N.	44 09·5	40	N.W.	2·053	+·006	2·059		
			N.S.	21 37·6	40						
April 1.	−53 13	135 18	S.	46 55·4	43		2·042	+·012	2·054		
			N.	44 41·5	40		2·017	+·012	2·029		
			N.S.	22 29·7	39						
			wt. 6 grs.	31 08·5	40		1·987	+·012	1·999	2·047	
			wt. 5 grs.	25 28·5	40		1·990	+·012	2·002		
			wt. 4 grs.	19 39·7	40		2·035	+·012	2·047		
			wt. 3 grs.	14 07·7	40		2·086	+·012	2·098		
			wt. 2 grs.	9 26·2	40	N.N.E.	2·086	+·012	2·098		
			wt. 1 gr.	5 10·2	40						
2.	−51 16	136 50	S.	47 16	43		2·020	+·013	2·033	2·041	
			N.	44 23·8	41		2·036	+·013	2·049		
			N.S.	22 18·5	39						
3.	−48 24	138 32	N.	45 01·5	43		....	......	....		Much motion and rolling deep.
			N.S.	22 56·3	44						
4.	−46 55	139 55	N.	46 33·4	45	N.E.	....	......	....		A heavy sea.
	−46 29	140 40	S.	48 37·8	44		1·927	+·015	1·942	1·949	A heavy sea running.
			N.	45 50·1	44	N.E.	1·941	+·015	1·956		
			N.S.	23 03	44						

Observations of the Magnetic Force. (Continued.)

1841.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity.		Remarks.
April 4.	−46° 22′	141° 06′	S.	48° 31′·5	45°	N.E. by E.	1·934	+·011	1·945	1·954	
			N.	45 40·2	45		1·952	+·011	1·963		
			N.S.	23 00·9	45						
5.	−45 02	143 10	S.	48 46·2	46	N.E. by E.	1·917	+·012	1·929	1·923	
			N.	46 15	47		1·913	+·012	1·925		
			N.S.	22 05·9	47						
			S.	48 49·8	50	N.E. by E.	1·912	+·013	1·925		
			N.	46 25·1	48		1·901	+·013	1·914		
6.	−43 41	146 03	S.	50 01·4	60	N.E. ½ E.	1·820	+·018	1·838	1·892	Running along the land.
			N.	46 39·8	60		1·884	+·018	1·902		
			N.S.	23 16·8	59						
			wt. 6 grs.	32 58·5	58		1·887	+·018	1·905		
			wt. 5 grs.	26 29·7	58		1·919	+·018	1·937		
			wt. 4 grs.	21 21	59		1·881	+·018	1·899		
			wt. 3 grs.	15 59·4	59		1·850	+·018	1·868		
			wt. 2 grs.	10 27·2	58		1·885	+·018	1·903		
			wt. 1 gr.	5 14·2	58		1·870	+·018	1·888		

Observations of Declination made on board Her Majesty's Ship Terror, between November 15, 1840, and April 5, 1841.

The Observers are distinguished by their Initials as follows:—C. Captain Crozier; P. Lieut. Phillips; Cr. Mr. Cotter, Master.

1840.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Corrected Declination (mean).	Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	° ′	
Nov 15.	−44 24	152 58	Cr.	− 6 57	s.e. by e.	−71 40	−4 44	−11 41	−13 01	+1 23	−11 38	Compass R. of Cummins, index error ascertained at Hobarton, June 1841.
	−44 24	152 58	Cr.	− 9 36	s.e. by e.		−4 44	−14 20				
16.	−46 05	154 18	C.	−10 52	s.e.		−4 09	−15 01				
	−46 11	154 18	Cr.	−12 57	s.e.	−72 00	−4 09	−17 06	−15 10	+1 23	−13 47	
	−46 11	154 18	Cr.	− 9 48	s.e.		−4 09	−13 57				
	−46 24	154 50	Cr.	− 9 48	s.e. by e.		−4 49	−14 37				
18.	−49 06	160 10	C.	−11 12	s.e. by e. ½ e.		−5 20	−16 32				
	−49 14	160 06	Cr.	−11 54	s.e. by e. ½ e.	−73 00	−5 20	−17 14	−16 07	+1 23	−14 44	
	−49 14	160 06	Cr.	− 9 39	s.e. by e. ½ e.		−5 20	−43 59				
	−49 40	160 52	C.	−11 23	s.e. by e. ½ e.		−5 20	−16 43				
	Auckland Island.											
Dec. 6.	−50 33	166 15	Cr.	−21 10	s.w. by w.		+5 09	−16 01				
	At anchor.		Cr.	−21 12	s.w. by w.		+5 09	−16 03				
			Cr.	−22 48	s.w.		+4 27	−18 21				
8.			Cr.	−12 11	e.n.e.		−5 07	−17 18				
			Cr.	−21 59	s.w. by w.		+5 09	−16 50				
11.			Cr.	−21 47	n.w. by w.		+4 29	−17 18				
			Cr.	−20 32	n.w. by w.		+4 29	−15 03				
			C.	−19 32	w.n.w.		+5 07	−14 25				
			C.	−19 47	w.n.w.		+5 07	−14 40				
			C.	−20 14	n.w. by w.		+4 29	−15 45				
			C.	−19 23	n.w.		+3 46	−15 37				
			C.	−22 09	w. by n.		+5 35	−16 34				
			C.	−21 28	n.w. by w.		+4 29	−16 59				
			C.	−20 29	n.w. by w. ½ w.		+4 48	−15 41				
			C.	−23 00	w.		+5 49	−17 11				
			C.	−22 07	w. by n. ½ n.		+5 21	−16 46				
			C.	−22 05	w. by n.		+5 35	−16 30				
			C.	−21 59	w. ½ n.		+5 42	−16 17				
			C.	−22 36	w. ¼ s.		+5 50	−16 46				
			C.	−21 40	w.	−73 10	+5 49	−15 51	−16 52	+1 23	−15 29	
			C.	−20 54	n.w. by w.		+4 29	−16 25				
			C.	−21 50	w.n.w.		+5 07	−16 43				
			C.	−24 23	w. by n.		+3 35	−18 48				
			Cr.	−20 20	n.w. by w.		+4 29	−15 51				
			Cr.	−20 29	n.w. by w.		+4 29	−16 00				
			Cr.	−19 39	n.w.		+3 46	−15 53				
			Cr.	−21 02	w.n.w.		+5 07	−15 55				
			Cr.	−21 19	w.n.w.		+5 07	−16 12				
			Cr.	−22 12	w.n.w.		+5 07	−17 05				
			Cr.	−21 49	w. by n.		+5 35	−16 14				
			Cr.	−21 52	w. by n.		+5 35	−16 17				
			Cr.	−23 29	w.		+5 49	−17 40				
12.			C.	−12 41	n.e.		−3 46	−16 27				
			C.	−13 20	n.e. by n.		−2 57	−16 17				
			C.	−13 49	n.n.e.		−1 58	−15 47				
			C.	−13 18	e.s.e.		−5 36	−18 54				
			C.	−13 18	s.e. by e.		−5 09	−18 27				
			Cr.	−13 21	n.e.		−3 46	−17 07				
			Cr.	−15 34	n.n.e.		−1 58	−17 32				
			Cr.	−15 17	n.e.		−3 46	−19 03				
			Cr.	−11 15	e. by s.		−5 51	−17 06				
			Cr.	−12 32	e.s.e.		−5 36	−18 08				

Observations of Declination. (Continued.)

1840.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	° ′	
Dec. 12.	−50 32	167 45	C.	−14 02	s.e. by e.	−73 00	−5 06	−19 08				
13.	−52 30	169 50	C.	−13 23	s.e. by e.		−5 22	−18 45				
	−52 30	169 50	C.	−12 57	s.e. by e.		−5 22	−18 19				
16.	−52 34	169 50	Cr.	−22 21	w. by s.		+6 08	−16 13				
	−52 34	169 50	Cr.	−21 49	w.s.w.		+5 50	−15 59				
	−52 34	169 50	Cr.	−22 50	w.s.w.	−73 53	+5 50	−17 00	−18 31	+1 23	−17 08	
	−52 34	169 50	Cr.	−23 01	s.w. by w.		+5 21	−17 40				
	−52 34	169 50	Cr.	−23 10	s.w. by w.		+5 21	−17 49				
	−52 34	169 50	Cr.	−19 55	s.w.		+4 38	−15 15				
17.	−52 34	169 50	Cr.	−12 59	e.s.e.		−5 50	−18 49				
	−52 34	169 50	Cr.	−12 53	e.s.e.		−5 50	−18 43				
20.	−56 39	168 54	Cr.	−14 11	s.s.e.	−76 30	−2 58	−17 09				
21.	−57 33	170 30	C.	−21 54	s.s.e.		−3 06	−25 00				
	−57 33	170 30	C.	−21 06	s.s.e.	−77 10	−3 06	−24 12				
	−57 33	170 30	C.	−20 28	s. by e.		−1 36	−22 04				
	−57 33	170 30	C.	−23 45	s. by e.		−1 36	−25 21				
22.	−58 54	171 02	Cr.	−25 00	s. by e.		−1 44	−26 44	−23 21	+1 23	−21 58	
	−58 54	171 02	C.	−20 41	s. by e. $\frac{1}{2}$ e.		−2 36	−23 17				
	−58 54	171 02	C.	−20 41	s.s.e.		−3 23	−24 04				
	−58 54	171 02	Cr.	−20 21	s.s.e.	−78 10	−3 23	−23 44				
	−59 04	171 00	C.	−26 54	s.s.w.		+3 23	−23 31				
	−59 04	171 00	C.	−25 15	s.s.w.		+3 23	−23 52				
	−59 09	170 45	C.	−26 34	s.s w.		+3 23	−23 11				
23.	−59 32	170 05	C.	−24 05	s.s.w. $\frac{1}{2}$ w.		+4 17	−19 48				
	−59 32	170 05	Cr.	−17 24	s.e.		−6 23	−23 47				
	−59 32	170 05	Cr.	−16 38	s.e. by e.		−7 23	−24 01				
	−59 32	170 05	Cr.	−18 02	s.e. by s.		−5 03	−23 05				
	−59 32	170 05	Cr.	−21 02	s.s.e.		−3 31	−24 33				
	−59 32	170 05	Cr.	−23 36	s.		0 0	−23 36				
	−59 32	170 05	Cr.	−24 03	s. by w.	−78 30	+1 48	−22 15	−22 19	+1 23	−20 56	
	−59 32	170 05	Cr.	−26 39	s.s.w.		+3 31	−23 08				
	−59 32	170 05	Cr.	−26 52	s.w. by s.		+5 03	−21 49				
	−59 32	170 05	Cr.	−28 17	s.w.		+6 23	−21 54				
	−59 32	170 05	Cr.	−29 01	s.w. by w.		+7 23	−21 38				
	−59 32	170 05	Cr.	−28 11	w. by n.		+8 11	−20 00				
	−59 22	170 05	Cr.	−28 10	w.n.w.		+7 36	−20 34				
23.	−59 32	170 05	Cr.	−27 50	n.w. by w.		+6 45	−21 05				
	−59 32	170 05	Cr.	−26 47	n.w.		+5 41	−21 06				
	−59 32	170 05	Cr.	−25 49	n.w. by n.		+4 26	−21 23				
	−59 32	170 05	Cr.	−23 55	n. by w.	−78 30	+1 33	−22 22	−21 43	+1 23	−20 20	
	−59 32	170 05	Cr.	−21 34	n.		0 0	−21 34				
	−59 32	170 05	Cr.	−20 17	n. by e.		−1 33	−21 50				
	−59 32	170 05	Cr.	−18 32	n.n.e.		−3 02	−21 34				
	−59 32	170 05	Cr.	−18 22	n.e. by n.		−4 26	−22 48				
	−59 37	169 17	C.	−14 38	s.s.e. $\frac{3}{4}$ e.		−4 53	−19 31				
	−59 37	169 17	C.	−15 17	s.s.e. $\frac{3}{4}$ e.		−4 53	−20 10				
24.	−60 17	170 12	C.	−25 59	s.		0 0	−25 59				
	−60 17	170 12	C.	−23 38	s.s.e.		−3 41	−27 19				
	−60 17	170 12	C.	−22 25	s.e. by s.		−5 17	−27 42				
	−60 17	170 12	C.	−23 51	s.s.e.	−79 00	−3 41	−27 32	−25 11	+1 23	−23 48	
	−60 17	170 12	C.	−22 00	s.e. $\frac{1}{2}$ s.		−6 00	−28 00				
	−60 35	170 34	Cr.	−18 19	s.e.		−6 41	−25 00				
	−60 35	170 34	Cr.	−17 57	s.e.		−6 41	−24 38				
	−60 35	170 34	Cr.	−21 50	s.s.e.		−3 41	−25 31				
	−60 35	170 34	Cr.	−21 14	s.s.e.		−3 41	−24 55				
	−60 35	170 34	Cr.	−20 40	s.e. by s.		−5 17	−25 57				

Observations of Declination. (Continued.)

1840.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	° ′	
Dec. 29.	−64 11	172 43	C.	−27 44	S. ½ E.		− 1 08	−28 52				
	−64 11	172 43	Cr.	−24 39	S. by E.		− 2 16	−26 55				
	−64 11	172 43	Cr.	−25 09	S. by E.		− 2 16	−27 25				
30.	−64 26	173 15	C.	−34 58	S.W.		+ 8 23	−26 35				
	−64 26	173 15	C.	−34 22	S.W.	−81 15	+ 8 23	−25 59	−27 15	+1 23	−25 52	
	−64 26	173 15	C.	−35 07	S.W. ½ S.		+ 7 30	−27 37				
	−64 26	173 15	C.	−32 54	S.S.W.		+ 4 34	−28 20				
	−64 48	172 56	Cr.	−25 15	S. by E.		− 2 16	−27 31				
	−64 48	172 56	Cr.	−34 20	S.W.		+ 8 23	−25 57				
31.	−65 42	172 13	C.	−26 09	S. ½ E.		− 1 10	−27 19				
	−65 42	172 13	C.	−26 13	S. by E.		− 2 24	−28 37				
	−65 42	172 13	C.	−25 23	S. by E.		− 2 24	−27 47				
	−65 42	172 13	Cr.	−26 26	S. by E.	−82 00	− 2 24	−28 40	−27 40	+1 23	26 17	
	−65 42	172 13	Cr.	−26 18	S. by E.		− 2 24	−28 42				
	−65 42	172 13	Cr.	−23 34	S. by E.		− 2 24	−25 58				
	−65 42	172 13	Cr.	−24 11	S. by E.		− 2 24	−26 35				
1841.												
Jan. 2.	−66 24	170 00	C.	−17 14	E. by S. ½ S.		−11 57	−29 11				
4.	−65 15	172 40	Cr.	−19 54	S.E.		− 9 09	−29 03				
	−65 15	172 40	Cr.	−20 48	S.E.		− 9 09	−29 57				
	−65 27	173 20	Cr.	−21 14	E. by S. ½ S.		−11 57	−33 11				
	−65 27	173 20	C.	−21 00	E. by S. ½ S.		−11 57	−32 57				
	−65 27	173 20	C.	−17 49	E. ½ S.	−82 00	−12 13	−30 02	−30 40	+1 23	−29 17	
	−65 27	173 20	C.	−19 17	E. by S. ½ S.		−11 57	−31 14				
	−65 30	173 30	C.	−20 04	E. by S. ½ S.		−11 57	−32 01				
	−65 30	173 30	C.	−21 11	E.S.E.		−11 44	−32 55				
	−65 31	173 40	C.	−22 19	S.E. by E.		−10 38	−32 57				
	−65 32	173 50	C.	−21 48	S.E. ½ E.		− 9 53	−31 41				
	−65 32	173 50	C.	−25 56	S.S.E. ½ E.		− 6 07	−32 03				
	−65 32	173 50	C.	−22 38	S.E. by E. ½ E.		−10 34	−33 12				
	−65 35	173 52	C.	−26 59	S.S.E.		− 4 41	−31 40				
	−65 35	173 52	C.	−26 54	S. by E.		− 2 18	−29 12				
	−65 35	173 52	C.	−25 22	S.S.E. ½ E.		− 5 45	−31 07				
	−65 35	173 52	C.	−25 54	S.S.E.		− 4 40	−30 34				
	−65 27	173 20	P.	−23 56	E. by S. ½ S.	−81 30	−11 16	−35 12	−31 05	+1 23	−29 42	
	−65 35	173 52	P.	−22 34	S.E. by E.		−10 02	−32 36				
	−65 28	173 20	Cr.	−18 25	E. by S.		−11 25	−29 50				
	−65 28	173 20	Cr.	−17 29	E.S.E.		−11 04	−28 33				
	−65 28	173 20	Cr.	−18 27	E.S.E.		−11 04	−29 31				
	−65 28	173 30	Cr.	−20 09	E.S.E.		−11 04	−31 13				
5.	−66 15	173 32	Cr.	−25 37	S.S.E.		− 4 41	−30 18				
6.	−68 07	175 12	Cr.	−30 21	S.S.E.		− 5 57	−36 18				
	−68 07	175 12	Cr.	−30 28	S.S.E.		− 5 57	−36 25				
7.	−68 30	175 30	Cr.	−24 25	S.E. by E.		−12 58	−37 43				
	−68 30	175 30	Cr.	−23 36	S.E. by E.		−12 58	−36 34				
	−68 30	175 30	Cr.	−23 42	S.E.	−83 30	−11 00	−34 42	−36 01	+1 23	−34 38	
	−68 30	175 30	Cr.	−23 12	E.S.E.		−14 09	−37 21				
	−68 30	175 30	Cr.	−47 46	S.W. by W.		+12 58	−34 48				
8.	−68 26	176 32	C.	−22 19	S.E. by E.		−12 58	−35 17				
	−68 26	176 32	C.	−20 36	S. 73° E.		−14 30	−35 06				
	−68 26	176 32	C.	−20 59	S. 85° E.		−14 56	−35 55				
11.	−70 53	173 00	C.	−45 31	S. ¼ E.		− 1 10	−46 41				
	−70 53	173 00	C.	−48 51	S. by W.		+ 4 43	−44 08				
	−70 53	173 00	C.	−43 10	S.		0 0	−43 10				
	−70 53	173 00	Cr.	−43 22	S.		0 0	−43 22				
	−70 53	173 00	Cr.	−44 57	S.	−85 50	0 0	−44 57	−46 48	+1 03	−45 45	A light card of Cummins, marked P, was now used. Index error ascertained at Hobarton, June 1841.

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.	Corrected Declination (mean).	Correction for index error.	True Declination.	Remarks.
Jan. 11.	−71° 21′	171° 14′	Cr.	− 49° 10′	s. ½ w.	−85° 50′	+ 2° 20′	− 46 50	− 46 48	+1° 03′	− 45° 45′	A light card of Cummins, marked P, was now used. Index error ascertained at Hobarton, June 1841.
	−71 21	171 14	C.	− 51 03	s.		0 0	− 51 03				
	−71 21	171 14	C.	− 53 04	s. by w.		+ 4 43	− 48 21				
	−71 21	171 14	C.	− 54 21	s. by w.		+ 4 43	− 49 38				
	−71 21	171 14	C.	− 54 32	s. by w.		+ 4 43	− 49 49				
	−71 21	171 14	C.	− 53 11	s. by w.		+ 4 56	− 48 15				
	−71 21	171 14	C.	− 51 22	s.		0 0	− 51 22				
	−71 21	171 14	C.	− 51 33	s. by w.		+ 4 56	− 46 37				
	−71 21	171 14	C.	− 50 08	s. by w.	−86 00	+ 4 56	− 45 12	− 47 55	+1 03	− 46 52	
	−71 21	171 14	Cr.	− 52 01	s. by w.		+ 4 56	− 47 05				
	−71 21	171 14	Cr.	− 53 19	s. by w.		+ 4 56	− 48 23				
	−71 21	171 14	Cr.	− 53 18	s. by w.		+ 4 56	− 48 22				
	−71 21	171 14	Cr.	− 53 00	s. by w.		+ 4 56	− 48 04				
	−71 48	171 21	C.	− 50 53	s. by w.		+ 4 56	− 45 57				
	−71 48	171 21	C.	− 57 58	s.w. by s.		+14 14	− 43 44				
	−71 48	171 21	C.	− 53 25	s. by w. ½ w.		+ 7 22	− 48 03				
	−71 48	171 21	C.	− 27 35	e. by s. ½ s.		−24 22	− 51 57				
	−71 48	171 21	Cr.	− 52 46	s.s.w.		+ 9 48	− 42 58				
	−71 48	171 21	Cr.	− 54 17	s.s.w.	−86 00	+ 9 48	− 44 29	− 47 43	+1 03	− 46 40	
	−71 48	171 21	Cr.	− 53 06	s. by w.		+ 4 56	− 48 10				
	−71 48	171 21	Cr.	− 53 11	s. by w.		+ 4 56	− 48 15				
	−71 48	171 21	Cr.	− 25 06	e. by s.		−25 04	− 50 10				
	−71 48	171 21	Cr.	− 26 50	e. by s.		−25 04	− 51 54				
	−72 06	171 07	Cr.	− 58 11	s.s.w.		+ 9 48	− 48 23				
	−72 06	171 07	Cr.	− 58 27	s.s.w.		+ 9 48	− 48 39				
17.	−72 24	174 45	C.	− 35 06	s.e. by e.		−21 21	− 56 27				
	−72 25	174 50	C.	− 35 46	s.e. ½ e.		−19 44	− 55 30				
	−72 13	173 59	Cr.	− 35 00	s.e. by e.		−21 21	− 56 21				
	−72 13	173 59	Cr.	− 35 00	s.e. by e.		−21 21	− 56 21				
	−72 25	174 26	Cr.	− 34 37	s.e. by e.		−21 21	− 55 58				
	−72 25	174 26	Cr.	− 34 19	s.e. by e.	−86 00	−21 21	− 55 40	− 53 38	+1 03	− 52 35	
18.	−73 03	176 20	C.	− 64 55	s.w. by s.		+14 14	− 50 41				
	−73 03	176 20	Cr.	− 64 17	s.w. by s.		+14 14	− 50 03				
	−73 03	176 20	Cr.	− 65 46	s.w. by s.		+14 14	− 51 32				
	−73 03	176 20	Cr.	− 62 42	s.s.w. ½ w.		+12 00	− 50 42				
	−73 03	176 20	Cr.	− 64 56	s.w. by s.		+14 14	− 50 42				
19.	−72 34	173 21	C.	− 68 00	s.w. ¼ s.		+16 53	− 51 07				
	−72 34	173 21	C.	− 68 37	s.w.		+18 55	− 49 42				
	−72 33	173 10	C.	− 66 01	s.w.		−18 55	− 47 06				
	−72 33	173 10	C.	− 67 00	s.w. ¼ s.	−86 10	+16 50	− 50 10	− 49 52	+1 03	− 48 49	
	−72 32	172 27	Cr.	− 69 35	s.w.		+18 55	− 50 40				
	−72 32	172 27	Cr.	− 67 12	s.w. ½ s.		+16 53	− 50 19				
	−72 32	172 27	Cr.	− 67 40	s.w.		+18 55	− 48 45				
	−72 32	172 27	Cr.	− 67 57	s.w. ½ s.		+16 53	− 51 04				
	−72 31	172 47	C.	− 44 51	s.s.e. ½ e.		−12 30	− 57 21				
	−72 31	172 47	C.	− 44 23	s.s.e. ½ e.		−12 30	− 56 53				
	−72 31	172 47	Cr.	− 43 53	s.s.e.		−10 12	− 54 05				
	−72 31	172 47	Cr.	− 45 36	s.s.e.	−86 10	−10 12	− 55 48	− 55 37	+1 03	− 54 34	
	−72 31	172 47	Cr.	− 49 19	s. by e.		− 5 08	− 54 27				
	−72 31	172 47	Cr.	− 54 17	s.		0 0	− 54 17				
	−72 31	172 47	Cr.	− 53 18	s.		0 0	− 53 18				
	−72 52	172 20	P.	− 48 34	s.s.e.		−10 12	− 58 46				
22.	−73 51	171 50	C.	− 34 19	e. by s.		−32 26	− 66 45				
	−73 51	171 50	C.	− 35 58	e. by s. ¼ s.		−31 56	− 67 44				
	−73 52	170 40	P.	44 12	n.e. ½ e.		−24 30	− 68 42				
	−73 44	171 03	Cr.	− 40 41	n.e. by n.	−86 50	−17 23	− 58 04	− 66 44	+1 03	− 65 41	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
Jan. 22.	−73 46	171 25	Cr.	− 42 16	N.E. ½ N.	−86 50	−24 30	− 66 46	− 66 44	+1 03	− 65 41	
	−73 46	171 25	Cr.	− 43 41	N.E. ½ N.		−24 30	− 68 11				
	−73 46	171 25	Cr.	− 36 51	E.N.E.		−29 58	− 66 49				
	−73 46	171 25	Cr.	− 36 16	E.N.E.		−29 58	− 66 14				
	−73 46	171 25	Cr.	− 36 32	E. by N.		−32 03	− 68 35				
	−73 46	171 25	Cr.	− 36 26	E. by N.		−32 03	− 68 29				
	−73 46	171 35	Cr.	− 36 14	E.		−31 04	− 67 18				
	−73 46	171 35	Cr.	− 36 12	E.		−31 04	− 67 16				
	−73 46	171 35	Cr.	− 36 50	E.		−31 04	− 67 54				
	−73 46	171 35	Cr.	− 35 47	E. by S.	−86 40	−30 36	− 66 23	− 65 15	+1 03	− 64 12	
	−73 59	171 40	C.	− 62 48	S.		0 0	− 62 48				
	−73 59	171 40	C.	− 63 52	S.		0 0	− 63 52				
	−74 03	171 40	C.	− 62 41	S.		0 0	− 62 41				
	−74 03	171 40	C.	− 63 47	S.		0 0	− 63 47				
	−74 04	173 09	C.	− 40 33	E. by S.		−27 31	− 68 04				
	−74 04	172 43	C.	− 40 47	E. by S.		−27 31	− 68 18				
	−74 04	172 43	Cr.	− 38 47	E. by S.	−86 20	−27 31	− 66 18	− 66 07	+1 03	− 65 04	
23.	−73 55	172 46	Cr.	− 62 02	S.		0 0	− 62 02				
	−73 59	171 32	Cr.	− 38 22	E. by S.		−27 31	− 65 33				
25.	−74 24	168 28	C.	− 77 13	S.S.W.		+13 46	− 63 27				
	−74 24	168 28	C.	− 81 13	S.S.W.		+13 46	− 67 27				
	−74 24	168 28	Cr.	− 80 24	S.S.W.	−87 10	+13 46	− 66 38	− 69 43	+1 03	− 68 40	
	−74 28	168 46	Cr.	− 39 28	E.S.E.		−34 13	− 73 41				
	−74 28	168 46	Cr.	− 38 39	E.S.E.		−34 13	− 72 52				
	−74 28	168 46	Cr.	− 39 57	E.S.E.		−34 13	− 74 10				
	−74 50	168 45	C.	− 43 23	E. by S.		−46 49	− 90 12				
	−75 37	168 28	C.	−102 27	S. by W.	−87 40	− 8 23	− 94 04				
26.	−74 45	168 48	Cr.	− 33 53	E. ½ S.		−47 08	− 81 01				
27.	−75 40	168 28	C.	− 53 33	E.S.E.		−36 33	− 90 06				
	−75 40	168 28	C.	− 56 14	E.S.E.		−36 33	− 92 47	− 91 47	+1 03	− 90 44	
	−75 40	168 28	C.	− 60 19	E.S.E.	−87 20	−36 33	− 96 52				
	−75 40	168 28	Cr.	− 55 50	E.S.E.		−36 33	− 92 23				
	−75 40	168 28	Cr.	− 56 52	E.S.E.		−36 33	− 93 25				
	−75 40	168 28	Cr.	− 58 39	E.S.E.		−36 33	− 95 12				
	−75 58	168 50	C.	− 72 06	S.E. ½ E.	−87 60	−28 16	−100 22	−100 44	+1 03	− 99 41	
	−75 58	168 50	C.	− 73 11	S.E. ½ E.		−28 16	−101 27				
28.	−76 47	169 26	C.	− 72 17	E. ¾ S.	−87 10	−36 36	−108 53	−108 08	+1 03	−107 05	
	−76 47	169 26	C.	− 70 45	E. by S.		−36 38	−107 23				
	−77 17	171 38	C.	− 81 31	E. ½ S.		−34 42	−116 13				
	−77 22	172 00	C.	− 80 29	E. ½ S.		−34 42	−115 01				
	−77 30	172 20	C.	−119 58	N. ¾ W.	−87 00	+ 4 46	−115 12	−115 24	+1 03	−114 21	
	−77 17	172 20	C.	−116 46	N. ¼ W.		+ 1 35	−115 11				
29.	−77 47	176 23	P.	− 98 39	N. by E.		− 6 21	−105 00				
	−77 47	176 23	P.	− 94 04	N. by E.		− 6 21	−100 25				
	−77 47	176 14	Cr.	−100 48	N.	−87 00	0 0	−100 48	−103 12	+1 03	−102 09	
	−77 46	176 38	C.	−123 50	N.W. by N.		+18 23	−105 27				
	−77 46	176 00	C.	−110 43	N. by W.		+ 6 21	−104 22				
31.	−77 06	187 30	Cr.	− 65 19	N.E.		−17 26	− 82 45				
	−77 06	187 42	C.	− 64 40	N.E.		−17 26	− 82 06				
Feb. 1.	−77 03	189 03	C.	− 76 06	S.E. by S.	−86 00	−14 14	− 90 20	− 86 12	+1 03	− 85 09	
	−77 03	189 03	C.	− 74 36	S.E. by S.		−14 14	− 88 50				
	−77 03	189 03	C.	− 77 11	S.S.E.		−19 48	− 86 59				
2.	−77 45	187 08	C.	− 74 47	S. 62° E.		−21 00	− 95 47				
	−77 45	187 08	C.	− 75 23	S.E. by E.		−20 29	− 95 52				
	−77 45	187 08	C.	− 76 56	S.E. by E.		−20 29	− 97 25				
	−77 45	187 08	C.	− 77 48	S. 50° E.	−85 50	−18 56	− 96 44	− 96 24	+1 03	− 95 21	

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	° ′	
Feb. 2.	−77 41	187 02	P.	− 75 39	E. by S. ½ S.	−85 50	−23 22	− 99 01	− 96 24	+1 03	− 95 21	
	−77 41	187 02	P.	− 73 43	E. by S. ½ S.		−23 22	− 97 05				
	−77 41	187 02	P.	− 74 56	S.E. ½ E.		−18 56	− 93 52				
	−77 43	187 01	C.	− 74 57	S.E. by E.		−20 29	− 95 26				
	−77 45	189 00	C.	−115 08	N. 74° W.		+23 07	− 92 01				
	−77 45	189 00	C.	−118 10	N. 80° W.		+24 00	− 94 10				
	−77 45	189 00	C.	− 77 37	N. 56° E.		−19 50	− 97 27				
	−77 45	189 00	C.	− 76 48	S. 56° E.	−85 50	−20 29	− 97 17	− 96 02	+1 03	− 94 59	
	−77 45	189 00	C.	− 75 16	E.S.E.		−22 41	− 97 57				
	−77 45	189 00	C.	− 74 39	E.S.E.		−22 41	− 97 20				
	−77 58	186 50	C.	− 77 31	S. 83° E.		−25 15	−102 46				
	−77 58	186 50	C.	− 76 06	S. 75° E.		−21 30	− 97 36				
	−77 58	186 50	Cr.	− 73 42	E. by S.	−86 00	−25 04	− 98 46	− 98 14	+1 03	− 97 11	
3.	−77 22	185 00	C.	−119 49	S. 74° W.		+21 49	− 98 00				
	−77 22	185 00	C.	−117 43	S. 67° W.		+23 39	− 94 04				
4.	−76 56	192 19	C.	− 77 32	S. 10° E.		− 4 31	− 82 03				
	−76 56	192 19	C.	− 59 49	N.E. by E. ½ E.		−20 10	− 79 59				
	−76 56	192 19	Cr.	− 62 37	E.N.E.		−21 18	− 83 55				
	−77 04	192 02	C.	− 62 30	E. by N.		−22 48	− 85 18				
	−77 04	192 02	C.	− 63 34	E. by N. ¾ N.		−21 40	− 85 14				
	−77 04	192 02	Cr.	− 61 20	E.N.E.		−21 18	− 82 38				
5.	−77 09	192 30	C.	− 96 17	S.S.W. ½ W.	−85 40	+11 12	− 85 05	− 84 06	+1 03	− 83 03	
	−77 09	192 30	C.	− 88 25	S. by W.		+ 4 31	− 83 54				
	−77 09	192 30	C.	− 83 24	S. ¼ E.		− 1 05	− 84 29				
	−77 09	192 30	C.	− 65 46	N.E. by E. ½ E.		−20 10	− 85 56				
	−77 12	192 30	P.	− 62 30	E. ½ N.		−23 06	− 85 36				
	−77 15	192 40	P.	− 64 04	E. ¾ N.		−22 57	− 87 01				
	−77 20	192 30	Cr.	− 93 11	S.S.W.		+ 9 03	− 82 08				
6.	−76 57	188 24	C.	− 88 27	S. ¾ W.		+ 3 42	− 84 45				
	−76 57	188 24	C.	− 86 19	S. ½ W.		+ 2 28	− 83 51				
	−76 57	188 24	C.	− 61 44	E.N.E.		−23 10	− 84 54				
	−76 57	188 24	C.	− 62 49	E. by N. ½ N.		−24 00	− 86 49				
	−76 57	188 24	C.	− 82 24	S. ¾ E.	−86 00	− 3 42	− 86 06	− 84 27	+1 03	− 83 24	
	−76 57	188 24	C.	− 93 19	S. by W. ¾ W.		+ 8 35	− 84 44				
	−76 57	188 24	P.	− 87 16	S. ½ W.		+ 2 28	− 84 48				
	−76 57	189 00	Cr.	− 84 11	S.		0 0	− 84 11				
	−76 59	188 45	Cr.	− 87 13	S. by W. ½ W.		+ 7 22	− 79 51				
7.	−76 56	186 21	C.	− 95 43	S. by W. ½ W.		+ 7 22	− 88 21				
	−76 56	186 21	C.	− 61 53	E.		−25 25	− 87 18				
	−76 56	186 21	C.	− 63 01	E.		−25 25	− 88 26				
	−76 56	186 21	C.	− 63 08	E. ¼ N.		−25 06	− 88 14				
	−77 10	187 10	Cr.	− 92 37	S. by W. ¾ W.		+ 8 35	− 84 02				
	−77 07	186 50	C.	− 72 58	S.E. by E. ½ E.	−86 00	−22 30	− 95 28	− 90 40	+1 03	− 89 37	
	−77 07	186 50	C.	− 70 33	E.S.E.		−23 39	− 94 12				
	−77 07	186 50	C.	− 77 19	S.E. ¾ S.		−15 12	− 92 31				
	−77 07	186 50	C.	− 75 44	S.E.		−18 07	− 93 51				
	−77 07	186 50	Cr.	− 76 11	S.E.		−18 07	− 94 18				
8.	−77 30	186 20	C.	− 65 18	E. ½ S.		−25 15	− 90 33				
	−77 32	186 30	C.	− 69 25	E. ¼ N.		−25 16	− 94 41				
	−77 32	186 30	C.	− 69 20	E. ½ N.		−25 07	− 94 27				
	−77 32	186 30	C.	− 69 39	E. ½ N.		−25 07	− 94 46				
	−77 32	186 30	C.	− 70 52	E. by N. ¾ N.	−86 00	−23 35	− 94 27	− 94 27	+1 03	− 93 24	
	−77 31	186 17	Cr.	− 72 06	S.E. by E. ¾ E.		−23 04	− 95 10				
	−77 37	186 30	Cr.	− 68 35	E.		−25 25	− 94 00				
	−77 46	187 22	P.	− 72 52	E.N.E.		−23 10	− 96 02				
	−77 52	187 40	Cr.	− 74 04	N.E. by E. ½ E.		−21 56	− 96 00				

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′		° ′	° ′	
Feb. 9.	−77 54	190 50	C.	−108 41	s.w. by s.		+14 14	− 94 27				
	−77 54	190 50	C.	−106 37	s.w. by s.		+14 14	− 92 23				
	−77 54	190 50	Cr.	−107 42	s.s.w. ½ w.		+12 01	− 95 41				
	−77 54	190 50	Cr.	−110 45	s.w. by s.	−86 00	+14 14	− 96 31	− 95 45	+1 03	− 94 42	
	−77 53	189 25	P.	−110 56	s.s.w. ½ w.		+12 01	− 98 55				
10.	−77 42	188 00	Cr.	−114 10	s.w. ¾ w.		+15 12	− 98 58				
	−77 43	187 07	P.	−111 30	s.w.		+18 07	− 93 23				
14.	−76 26	177 19	C.	−101 52	s.s.w.	−87 00	+13 01	− 88 51	− 89 58	+1 03	− 88 55	
	−76 25	177 50	Cr.	−104 06	s.s.w.		+13 01	− 91 05				
15.	−76 31	168 30	C.	− 82 26	s.s.e. ¾ e.		−22 47	−105 13				
16.	−76 30	166 15	C.	− 67 30	s.e.		−32 02	− 99 32				
	−76 30	166 15	C.	− 65 14	e. by s.		−46 49	−112 03				
	−76 30	166 15	C.	− 70 38	e. by s.		−46 49	−117 27				
	−76 30	166 15	C.	− 74 30	e. ½ n.	−87 40	−46 47	−111 17	−112 47	+1 03	−111 44	
	−76 30	166 15	C.	− 82 25	n.e. by e.		−37 36	−120 01				
	−76 30	166 15	P.	− 73 22	e. ½ n.		−46 47	−120 09				
	−76 30	166 15	Cr.	− 66 43	e. by s. ¾ s.		−44 28	−111 11				
	−76 39	166 20	C.	− 72 58	e. by s. ½ s.		−45 14	−118 12				
18.	−76 05	166 30	C.	−144 55	w. by n. ½ n.		+45 20	− 99 35				
	−76 05	166 30	C.	−131 51	n.w.		+31 21	−100 30				
	−76 00	167 00	C.	−140 50	n.w. by w.	−87 40	+37 36	−103 14	−101 17	+1 03	−100 14	
	−76 05	165 49	Cr.	− 51 37	e.		−47 27	− 99 04				
	−76 05	165 49	C.	− 56 46	e. ¼ s.		−47 17	−104 03				
	−76 00	167 00	C.	−129 44	w.n.w.	−87 40	+42 44	− 87 00	− 90 35	+1 03	− 89 32	
19.	−75 12	168 30	C.	−100 16	s. ¾ w.		+ 6 05	− 94 11				
	−74 51	168 10	C.	−110 40	s.w.		+38 02	− 72 38				
	−74 51	168 10	C.	−109 33	s.w.	−88 00	+38 02	− 71 31	− 71 55	+1 03	− 70 52	
	−74 51	168 10	C.	−110 11	s.w.		+38 02	− 72 09				
	−74 51	168 10	Cr.	−109 24	s.w.		+38 02	− 71 22				
20.	−72 22	171 11	Cr.	− 72 08	w. by n.	−86 20	+27 13	− 44 55				
22.	−70 22	170 00	C.	− 19 00	e.n.e.		−21 18	− 40 18				
	−70 20	166 50	Cr.	− 21 22	e. by n.		−22 48	− 44 10				
24.	−70 22	167 12	C.	− 45 30	s. ¼ e.		− 1 07	− 46 37				
	−70 32	167 34	Cr.	− 59 52	w. by n. ¾ n.		+21 40	− 38 12				
	−70 32	167 34	Cr.	− 57 07	n.w. ¼ w.	−85 40	+16 48	− 40 19	− 38 44	+1 03	− 37 41	
25.	−70 09	167 20	C.	− 48 07	n.w. ¾ n.		+13 34	− 34 33				
	−70 09	167 20	C.	− 46 51	n.w.		+16 03	− 30 48				
	−70 03	167 30	C.	− 51 55	n.w. ½ w.		+17 32	− 34 23				
	−70 03	167 30	C.	− 50 19	n.w. by w.		+19 01	− 31 18				
	−70 03	167 30	C.	− 46 14	s. by w. ½ w.		+ 5 38	− 40 36				
26.	−69 51	167 50	C.	− 53 54	w. by s.		+22 06	− 31 48				
	−69 51	167 50	C.	− 53 23	w. by s. ½ s.		+21 30	− 31 53				
	−68 48	167 42	Cr.	− 55 05	w. by s.		+22 06	− 32 59				
	−68 48	167 42	Cr.	− 51 31	w. by s. ½ s.	−85 30	+21 48	− 29 43	− 37 09	+1 03	− 36 06	
27.	−69 26	167 40	Cr.	− 47 25	s. by w.		+ 4 20	− 43 05				
28.	−69 55	167 30	Cr.	− 39 10	s. by e. ½ e.		− 6 31	− 45 41				
Mar. 1.	−69 01	168 00	Cr.	− 36 08	s.s.e.		− 8 43	− 44 51				
2.	−68 10	167 37	C.	− 45 52	w. by n. ½ n.		+15 28	− 30 24				
	−68 10	167 37	C.	− 45 17	n.w.by w.½ w.		+14 15	− 31 02				
	−68 10	167 37	C.	− 46 45	w.n.w.		+14 56	− 31 49				
	−68 19	167 50	Cr.	− 46 49	w. by n.	−84 00	+16 01	− 30 48	− 28 09	+1 03	− 27 06	
5.	−65 32	167 20	C.	− 28 22	s. by w. ½ w.		+ 4 53	− 23 29				
	−65 32	167 20	C.	− 26 58	s. by w.		+ 3 17	− 23 41				
	−65 32	167 40	C.	− 32 43	s. by w. ½ w.		+ 4 53	− 27 50				
	−65 32	167 40	C.	− 32 48	s.s.w.		+ 6 29	− 26 19				

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′		° ′	° ′	
Mar. 6.	−65 50	164 40	C.	−37 12	s.s.w. ½ w.		+ 7 36	−29 36				
	−65 50	164 40	C.	−35 02	s.s.w.		+ 6 12	−28 50				
	−65 50	164 40	C.	−34 22	s.s.w.		+ 6 12	−28 10				
	−65 50	164 40	C.	−33 23	s. by w. ½ w.		+ 4 40	−28 43				
	−65 50	164 40	C.	−38 53	s.w. by s.	−83 45	+ 8 59	−29 54	−27 59	+1 03	−26 56	
	−65 50	164 40	C.	−39 02	s.w. ½ s.		+10 13	−29 08				
	−65 50	164 40	Cr.	−38 29	s.w.		+11 27	−27 02				
	−65 47	164 30	C.	−40 08	w. ¾ n.		+15 23	−24 35				
	−65 50	164 37	Cr.	−42 20	w. ½ s.		+15 35	−26 45				
7.	−65 34	162 08	C.	−29 08	n. by w. ½ w.		+ 4 08	−25 00				
	−65 34	162 08	C.	−27 42	n. by w. ½ w.		+ 4 08	−23 34				
	−65 34	162 08	C.	−29 19	n.n.w.		+ 5 31	−23 48				
	−65 34	162 08	C.	−36 28	n.w.	−83 30	+10 19	−26 09	−24 50	+1 03	−23 47	
	−65 34	162 08	C.	−16 26	s.e. by e.		−12 58	−29 26				
	−65 34	162 08	Cr.	−25 28	n. by w. ½ w.		+ 4 08	−26 08				
8.	−64 44	162 20	C.	−25 24	n. by e. ½ e.		− 3 49	−29 13				
	−64 44	162 20	C.	−23 05	n.n.e.		− 5 07	−28 12				
	−64 44	162 20	C.	−20 49	n.n.e. ½ e.		− 6 18	−27 07				
	−64 44	162 20	C.	−19 40	n.e. ½ n.		− 8 31	−28 11				
	−64 44	162 20	Cr.	−18 01	n.e. ½ e.		−10 32	−28 33				
9.	−64 20	164 34	C.	−30 53	s. by w.	−83 00	+ 2 43	−28 10	−28 01	+1 03	−26 58	
	−64 20	164 34	C.	−31 16	s. by w. ¼ w.		+ 3 25	−27 51				
	−64 23	164 15	C.	−33 23	s.s.w. ½ w.		+ 6 48	−26 35				
	−64 23	164 15	C.	−32 17	s.s.w. ¼ w.		+ 6 10	−26 07				
	−64 22	164 30	Cr.	−31 51	s. by w.		+ 2 43	−29 08				
11.	−64 10	163 00	C.	−34 24	n.w. ½ w.		+10 32	−23 52				
	−64 10	163 00	C.	−32 34	n.w. ½ w.		+10 32	−22 02				
	−64 18	163 15	Cr.	−33 14	n.w. by w.		+11 30	−21 44				
	−64 18	163 15	Cr.	−32 42	n.w.	−83 00	+ 9 34	−23 08	−24 11	+1 23	−22 48	Card R substituted.
	−64 00	163 00	C.	−33 44	n.n.w. ½ w.		+ 6 17	−27 27				
	−64 00	163 00	C.	−35 55	s.w. ¾ s.		+ 9 06	−26 49				
	−64 00	163 00	C.	−35 23	s.w. ¾ s.		+ 9 06	−24 17				
	−64 04	162 40	C.	−36 53	s.w. by w.		+12 00	−24 53				
	−64 04	162 40	C.	−37 54	s.w.byw.½w.		+12 34	−25 20				
	−64 04	162 40	C.	−38 41	w.s.w.		+13 09	−25 32				
12.	−64 04	160 53	C.	−34 41	w. ½ s.	−83 00	+13 51	−20 50	−23 42	+1 23	−22 19	
	−64 04	160 53	C.	−34 28	w. by s.		+13 48	−20 40				
	−64 07	161 20	C.	−29 30	s.s.w. ½ w.		+ 6 48	−22 42				
	−64 07	161 20	C.	−37 55	s.w. by w.		+12 00	−25 55				
14.	−62 49	157 00	C.	−22 39	s.s.e.		− 5 24	−28 03				
	−62 49	157 00	C.	−22 32	s.s.e.		− 5 24	−27 56				
	−62 49	157 00	C.	−21 53	s. by e. ½ e.		− 4 00	−25 53				
	−62 49	157 00	C.	−22 42	s. by e. ¾ e.	−82 45	− 4 42	−27 24	−28 12	+1 23	−26 49	
	−62 49	157 00	Cr.	−24 05	s.s.e.		− 5 24	−29 29				
	−62 55	157 07	Cr.	−25 07	s.s.e.		− 5 24	−30 31				
	−62 55	157 07	Cr.	−22 42	s.s.e.		− 5 24	−28 06				
18.	−63 50	151 35	C.	−21 06	s. by w.		+ 3 06	−18 00				
	−63 50	151 35	C.	−17 35	s. ½ e.		− 1 30	−18 05				
	−63 50	151 35	C.	−14 57	s. by e. ½ e.		− 4 30	−19 27				
	−63 50	151 35	C.	−14 47	s.s.e.		− 6 12	−20 59				
	−63 50	151 35	C.	−17 05	s. by e. ¼ e.		− 3 50	−20 55				
	−63 50	151 35	C.	−21 27	s. ½ w.	−83 45	+ 1 30	−19 57	−19 54	+1 23	−18 31	
	−63 50	151 35	C.	−29 36	s.w.		+11 27	−18 09				
	−63 50	151 35	C.	−22 16	s. ½ w.		+ 1 30	−20 46				
	−63 50	151 35	Cr.	−19 32	s. ½ e.		− 1 30	−21 02				
	−63 50	151 35	Cr.	−15 30	s.s.e.		− 6 12	−21 42				

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′		° ′	° ′	
Mar. 19.	−64 15	149 00	C.	−24 28	S.W. ½ S.		+11 11	−13 17				
	−64 15	149 00	C.	−24 03	S.S.W. ¾ W.		+ 9 05	−14 58				
	−64 15	149 00	C.	−17 37	S.S.W.		+ 6 45	−10 52				
	−64 15	149 00	C.	−23 31	S.S.W. ½ W.	−84 15	+ 8 19	−15 12	−15 22	+1 23	−13 59	
	−64 15	149 00	Cr.	−28 00	S.W. by S.		+ 9 50	−18 10				
	−64 15	149 00	Cr.	−25 51	S.W. by S.		+ 9 50	−16 01				
	−64 27	148 12	C.	−28 51	S.W. by S.		+ 9 50	−19 01				
21.	−64 05	140 00	C.	−21 49	W. ½ N.		+16 13	− 5 36				
	−64 05	140 00	C.	−21 13	W. by N.		+16 01	− 5 12				
22.	−63 10	139 30	C.	−17 14	N.W. ½ W.		+12 25	− 4 49				
	−63 10	139 30	C.	−15 50	N.W. ½ N.		+10 02	− 5 48				
	−63 10	139 30	C.	−18 22	N.W. ¼ W.	−84 00	+11 51	− 6 31	− 4 52	+1 23	− 3 29	
	−63 06	139 40	C.	−16 01	N.W. by W.		+13 34	− 2 27				
	−63 06	139 40	C.	−17 47	N.W. ½ W.		+12 25	− 5 22				
	−63 06	139 40	C.	−15 36	N.W. ½ W.		+12 25	− 3 11				
23.	−62 25	136 30	C.	−11 46	N.W. by N.		+18 24	− 3 22				
	−62 25	136 30	C.	−12 04	N.W. ¼ W.		+11 20	− 0 44				
	−62 05	136 00	C.	−13 15	W. by N. ¼ N.	−83 45	+15 02	+ 1 47	+ 0 12	+1 23	+ 1 35	
	−62 05	136 00	C.	−14 54	W. by N.		+15 17	+ 0 23				
	−62 05	136 00	C.	−11 20	W.N.W.		+14 16	+ 2 56				
25.	−60 23	131 38	C.	− 2 53	N.W. ½ N.		+ 8 43	+ 5 50				
	−60 23	131 38	C.	− 0 35	N.W. ½ N.		+ 8 43	+ 8 08				
	−60 23	131 38	C.	− 3 15	N.W. ½ N.		+ 8 43	+ 5 28				
	−60 23	131 38	C.	− 4 53	N.W. ½ W.		+10 48	+ 5 55				
	−60 23	131 38	C.	− 4 12	N.W.		+ 9 48	+ 5 36				
	−60 23	131 38	C.	− 2 17	N.W. ½ N.	−83 10	+ 8 43	+ 6 26	+ 6 52	+1 23	+ 8 15	
	−60 23	131 38	C.	− 2 24	N.W. ½ N.		+ 8 43	+ 6 19				
	−60 23	131 38	C.	− 2 34	N.W. ½ N.		+ 9 15	+ 6 41				
	−60 33	131 37	Cr.	− 0 41	N.W.		+ 9 48	+ 9 07				
	−60 33	131 37	Cr.	− 1 58	N.W.		+ 9 48	+ 7 50				
	−60 23	131 38	Cr.	− 1 34	N.W.		+ 9 48	+ 8 14				
	−60 20	131 30	C.	− 5 54	W. by N. ½ N.		+13 06	+ 7 12				
	−60 20	131 30	C.	+ 8 02	N. ½ W.		+ 1 15	+ 9 17				
	−60 20	131 30	C.	− 3 25	N.W.byW.½W.		+12 05	+ 8 40				
	−60 20	131 30	C.	+ 8 30	N. ¾ W.		+ 1 53	+10 23				
	−60 20	131 30	C.	+ 8 05	N. ¾ W.	−83 00	+ 1 53	+ 9 58	+ 9 00	+1 23	+10 23	
	−60 20	131 30	C.	− 1 55	N.W.byW.¼W.		+11 48	+ 9 53				
	−60 20	131 30	C.	+12 22	N.N.E.		− 5 07	+ 7 15				
	−60 20	131 30	C.	+19 22	N.E. by N.		− 7 28	+11 54				
	−60 20	131 30	C.	+13 35	N.N.E.		− 5 07	+ 8 28				
	−60 20	131 30	C.	− 4 58	N.W.byW.½W.		+12 05	+ 7 07				
26.	−59 24	129 46	C.	− 0 17	N.W. ½ N.		+ 8 15	+ 7 58				
	−59 12	129 40	C.	+ 7 47	N. ¾ W.		+ 1 49	+ 9 36				
	−59 12	129 40	C.	+ 4 29	N. by W. ¼ W.		+ 3 03	+ 7 32				
	−59 12	129 40	C.	+ 2 34	N.N.W. ¼ W.	−82 45	+ 5 32	+ 8 06	+ 8 44	+1 23	+10 07	
	−59 12	129 40	C.	+ 1 08	N.N.W. ¾ W.		+ 6 41	+ 7 49				
	−59 12	129 40	C.	+ 5 05	N.N.W.		+ 4 58	+10 03				
27.	−58 00	129 45	C.	+10 02	N.		0 0	+10 02				
28.	−57 22	127 40	C.	− 4 55	W. by S. ¾ S.		+11 30	+ 6 35				
	−57 22	127 40	C.	− 3 41	W. by S.		+11 48	+ 8 07				
	−57 22	127 40	C.	− 2 00	W. ½ S.		+11 49	+ 9 49				
	57 22	127 40	C.	+14 24	E. by N. ¾ N.	−81 45	−11 04	+ 3 20	+ 7 14	+1 23	+ 8 37	
	−57 22	127 40	Cr.	− 2 19	W. ½ N.		+11 47	+ 9 28				
	−57 22	127 40	Cr.	− 0 44	W. ½ N.		+11 47	+11 03				
	−57 22	127 40	C.	+12 27	N.E. ½ E.		− 8 58	+ 3 29				
	· 57 22	127 40	C.	+14 56	N.E. ½ E.		− 8 58	+ 5 58				

Observations of Declination. (Continued.)

1841.	Position. Lat.	Position. Long.	Observers.	Declination observed.	Direction of ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Correction for index error.	True Declination.	Remarks.
	° ′	° ′		° ′		° ′	° ′	° ′	° ′	° ′	° ′	
Mar. 29.	−56 35	129 50	C.	+15 58	N.E. by E. ½ E.		− 9 41	+ 6 17				
	−56 35	129 50	C.	+10 23	N.E. ½ E.		− 8 25	+ 1 58				
	−56 35	129 50	C.	+14 24	N.E.		− 7 41	+ 6 43				
	−56 44	129 37	Cr.	+11 40	E. by N.	−81 15	−11 01	+ 0 39	+ 3 58	+1 23	+5 21	
	−56 47	129 30	Cr.	+11 35	N.E. by N.		− 6 00	+ 5 35				
	−56 47	129 30	Cr.	+ 9 11	N.E. by N.		− 6 00	+ 3 11				
	−56 30	130 10	C.	+ 8 56	N.E. E. ¾ E.		− 5 31	+ 3 25				
30.	−55 12	132 00	C.	+ 7 38	N.E. by E. ½ E.		− 8 38	− 1 00				
	−55 12	132 00	C.	+ 1 47	N.E.		− 6 50	− 5 03				
	−55 12	132 00	C.	+ 4 15	N.E. ½ N.		− 6 05	− 1 50				
	−55 12	132 00	C.	+ 5 18	N.E. ½ N.	−80 20	− 6 05	− 0 47	− 0 38	+1 23	+0 45	
	−55 12	132 00	C.	+ 8 28	N.E.		− 6 50	+ 1 38				
	−55 12	132 00	C.	+ 2 52	N.E. by N.		− 5 20	− 2 28				
	−55 12	132 00	Cr.	+ 7 20	N. by E. ¾ E.		− 3 13	+ 4 07				
	−55 04	132 10	C.	+ 2 37	N. ½ E.		− 0 50	+ 1 47				
	−55 04	132 10	C.	+ 8 00	N.E. by E.		− 8 24	− 0 24				
	−55 04	132 10	C.	+ 2 37	N.N.E. ½ E.	−80 20	− 4 40	− 2 03	− 1 07	+1 23	+0 16	
	−55 04	132 10	C.	−00 04	N. ¾ E.		− 1 26	− 1 22				
	−55 04	132 10	C.	+ 3 45	N.E. ¼ E.		− 7 18	− 3 33				
	−54 56	132 15	C.	+ 4 43	N.E. by N.		− 5 32	− 0 49				
	−54 56	132 15	C.	+ 3 24	N.N.E. ¾ E.		− 5 01	− 1 37				
	−54 56	132 15	C.	+ 0 32	N. by E. ¾ E.	−80 20	− 3 13	− 2 41	− 1 29	+1 23	−0 06	
	−54 56	132 15	C.	+ 2 57	N. ¾ E.		− 1 26	+ 1 31				
	−55 06	132 07	Cr.	+ 1 47	N.N.E.		− 3 48	− 2 01				
	−55 01	132 15	Cr.	+ 2 46	N.E. ½ N.		− 6 05	− 3 19				
	−54 05	134 50	C.	+ 4 03	E. by N. ½ N.		− 8 33	− 4 30				
	−54 05	134 50	C.	+ 6 12	E.N.E.		− 8 15	− 2 03				
	−54 05	134 50	C.	+ 2 07	E. by N. ½ N.		− 8 24	− 6 17				
	−54 05	134 50	C.	+ 2 25	E. ½ N.		− 9 01	− 6 36				
	−54 05	134 50	C.	+ 2 07	E. ¾ N.		− 8 56	− 6 49				
	−54 05	134 50	C.	+ 6 00	E. ½ N.	−79 15	− 9 01	− 3 01	− 5 07	+1 23	−3 44	
	−54 06	134 31	Cr.	+ 5 19	E. by N.		− 8 52	− 3 33				
	−54 06	134 31	Cr.	+ 2 53	E. by N.		− 8 52	− 5 59				
	−54 06	134 31	Cr.	+ 4 27	E. by N.		− 8 52	− 4 25				
	−54 06	134 39	Cr.	+ 1 34	E.		− 9 10	− 7 36				
	−54 06	134 48	Cr.	+ 3 38	E.		− 9 10	− 5 32				
April 1.	−53 01	134 50	C.	− 0 30	N.N.E. ¾ E.		− 4 18	− 4 48				
	−53 01	134 50	C.	− 0 46	N.E. ½ E.		− 6 33	− 7 19				
	−52 54	135 10	C.	− 0 44	N.N.E. ¾ E.		− 4 18	− 5 02				
	−52 54	135 10	C.	− 1 52	N. by E. ¼ E.	−79 00	− 2 01	− 3 53	− 5 18	+1 23	−3 55	
	−52 54	135 10	C.	− 1 18	N. by E. ½ E.		− 2 25	− 3 43				
	−52 54	135 10	C.	− 2 56	N. by E. ½ E.		− 2 25	− 5 21				
	−52 54	135 10	C.	− 1 47	N.N.E.		− 3 12	− 4 59				
	−52 54	135 10	C.	− 4 08	N.N.E.		− 3 12	− 7 20				
2.	−51 16	136 49	Cr.	− 5 35	N. by E. ¾ E.		− 2 23	− 7 58				
	−51 16	136 49	C.	− 4 12	N. by E. ¼ E.	−77 30	− 1 44	− 5 56	− 7 01	+1 23	−5 38	
	−51 14	136 50	C.	− 2 00	N.E.		− 5 09	− 7 09				
5.	−44 53	143 00	Cr.	− 7 44	N.E.		− 3 43	−11 27				
	−44 53	143 00	C.	− 7 22	N.E.		− 3 43	−11 05				
	−44 56	143 16	C.	− 7 12	N.E. by E.		− 4 26	−11 38				
	−44 40	143 50	C.	− 8 16	N.E.		− 3 43	−11 59				
	−44 40	143 50	C.	− 7 21	N.E. ¾ E.		− 4 00	−11 21				
	−44 56	143 16	Cr.	− 1 23	E.N.E.	−73 00	− 5 04	− 6 27	−10 02	+1 23	−8 39	
	−44 50	143 20	Cr.	− 2 22	S.E.		− 4 24	− 6 46				
	−44 50	143 20	Cr.	− 6 19	S.S.E. ½ E.		− 3 00	− 9 19				
	−44 05	145 30	C.	− 7 16	N.E. ½ E.		− 4 04	−11 20				
	−44 05	145 30	C.	− 5 01	N.E. ½ E.		− 4 04	− 9 09				
	−44 05	145 30	C.	− 5 57	N.E. ¼ E.		− 3 53	− 9 50				

General Table of the Declinations observed on board Her Majesty's Ships Erebus and Terror, between November 1840 and April 1841.

Lat.	Long.	Ship.	No. of observations.	Declination.
° ′	° ′			° ′
+ 15° to + 5°.				
−60 20	131 30	Terror.	10	+10 23
−59 03	129 33	Terror.	7	+10 07
−57 21	127 45	Erebus.	10	+ 8 47
−57 22	127 40	Terror.	8	+ 8 37
−58 54	129 38	Erebus.	11	+ 8 32
−60 20	131 21	Erebus.	8	+ 8 18
−60 25	131 38	Terror.	11	+ 8 15
−60 25	131 37	Erebus.	10	+ 8 09
−60 20	131 22	Erebus.	7	+ 7 38
−56 14	130 44	Erebus.	8	+ 5 46
−56 39	129 45	Terror.	7	+ 5 21
+ 5° to − 5°.				
−62 13	136 12	Terror.	5	+ 1 35
−55 11	131 31	Erebus.	7	+ 1 34
−55 04	132 44	Erebus.	9	+ 1 09
−55 12	132 00	Terror.	7	+ 0 45
−55 13	131 15	Erebus.	7	+ 0 31
−55 04	132 10	Terror.	5	+ 0 16
−54 59	132 13	Terror.	6	− 0 06
−62 06	136 07	Erebus.	6	− 0 27
−52 52	135 26	Erebus.	7	− 1 03
−62 15	136 23	Erebus.	7	− 1 13
−54 04	134 45	Erebus.	7	− 1 44
−54 04	134 30	Erebus.	6	− 1 50
−63 22	139 41	Terror.	8	− 3 29
−54 05	134 44	Terror.	11	− 3 44
−52 56	135 05	Terror.	8	− 3 55
−62 37	138 24	Erebus.	6	− 4 05
−51 11	136 54	Erebus.	5	− 4 39
− 5° to − 15°.				
−51 15	136 49	Terror.	3	− 5 38
−63 13	140 00	Erebus.	12	− 5 58
−64 20	140 40	Erebus.	6	− 6 57
−44 37	143 56	Terror.	11	− 8 39
−44 18	145 04	Erebus.	9	− 8 46
−42 52	147 24	Erebus.	6	−10 24
−44 24	152 58	Terror.	2	−11 38
−65 04	142 47	Erebus.	2	−12 37
−45 36	152 53	Erebus.	8	−13 09
−46 08	154 15	Erebus.	8	−13 38
−46 13	154 26	Terror.	4	−13 47
−46 30	154 55	Erebus.	7	−13 58
−64 17	148 52	Terror.	7	−13 59
−49 18	160 18	Terror.	4	−14 44
− 15° to − 25°.				
−50 33	166 15	Terror.	42	−15 29
−50 54	166 35	Erebus.	7	−16 03
−52 22	169 38	Terror.	11	−17 08
−49 47	161 00	Erebus.	8	−17 16
−64 17	149 03	Erebus.	5	−17 19
−50 32	166 12	Erebus.	6	−17 44
−52 33	169 09	Erebus.	2	−17 52
−63 50	151 35	Terror.	10	−18 31
−54 14	169 06	Erebus.	5	−18 44
−63 50	151 48	Erebus.	6	−18 59
−63 52	151 51	Erebus.	6	−20 15
−59 32	170 05	Terror.	8	−20 20
−59 32	170 05	Terror.	13	−20 56
−59 32	169 59	Erebus.	8	−21 28
−57 10	170 06	Erebus.	7	−21 58
−58 19	170 39	Terror.	12	−21 58
−57 40	170 26	Erebus.	7	−21 59
−64 05	161 47	Terror.	7	−22 19
−60 47	170 55	Erebus.	11	−22 32
−64 08	163 04	Terror.	7	−22 48
−60 13	170 25	Erebus.	10	−22 49
−65 34	162 08	Terror.	6	−23 47
−60 18	170 12	Terror.	12	−23 48
−64 05	161 13	Erebus.	9	−24 06
−63 10	156 25	Erebus.	9	−24 07
− 25° to − 35°.				
−65 06	172 20	Erebus.	8	−25 06
−64 10	163 14	Erebus.	11	−25 18
−64 18	172 31	Erebus.	9	−25 33
−64 26	173 00	Terror.	9	−25 52
−64 52	162 42	Erebus.	9	−25 54
−64 40	172 44	Erebus.	8	−25 57
−65 42	172 13	Terror.	7	−26 17
−62 50	157 01	Terror.	7	−26 49
−65 50	164 39	Terror.	9	−26 56
−64 33	163 23	Terror.	10	−26 58
−66 52	167 35	Terror.	8	−27 06
−65 57	171 45	Erebus.	7	−27 11
−66 27	169 44	Erebus.	8	−27 21
−65 27	172 29	Erebus.	11	−27 34
−65 30	172 34	Erebus.	10	−28 08
−66 20	169 51	Erebus.	9	−28 21
−65 43	165 10	Erebus.	13	−28 23
−65 31	173 05	Terror.	12	−29 17
−65 35	173 38	Terror.	12	−29 42
−67 16	174 41	Erebus.	16	−31 29
−67 56	167 31	Erebus.	8	−32 35
−68 31	176 05	Erebus.	12	−33 52
−68 00	175 05	Erebus.	13	−34 04
−68 24	175 45	Terror.	10	−34 38
−68 28	176 32	Erebus.	1	−34 39
−68 55	176 20	Erebus.	5	−34 58
− 35° to − 45°.				
−69 23	167 45	Terror.	7	−36 06
−68 59	167 46	Erebus.	12	−36 12
−70 27	167 57	Terror.	11	−37 41
−69 33	167 31	Erebus.	11	−38 21
−70 03	167 30	Erebus.	10	−39 21

General Table of Declination. (Continued.)

Lat.	Long.	Ship.	No. of observations.	Declination.
° ′	° ′			° ′
		− 35° to − 45°.		
−70 33	172 57	Erebus.	6	−39 35
−70 23	167 23	Erebus.	7	−39 45
−71 00	172 25	Erebus.	9	−43 56
−71 22	170 56	Erebus.	10	−44 01
−71 51	171 53	Erebus.	9	−44 24
		− 45° to − 55°.		
−71 08	172 07	Terror.	10	−45 45
−71 52	171 19	Terror.	12	−46 40
−71 21	171 14	Terror.	8	−46 52
−71 55	172 00	Erebus.	9	−48 12
−72 33	172 51	Terror.	8	−48 49
−72 36	173 40	Erebus.	5	−50 31
−72 16	174 09	Erebus.	6	−51 41
−72 36	173 46	Erebus.	8	−51 54
−72 40	175 17	Terror.	11	−52 35
−73 01	175 55	Erebus.	12	−52 41
−72 34	172 43	Terror.	8	−54 34
		− 55° to − 65°.		
−73 57	171 23	Erebus.	12	−63 38
−73 53	171 37	Terror.	8	−64 12
−74 01	171 42	Erebus.	10	−64 25
		− 65° to − 75°.		
−74 01	172 35	Terror.	5	−65 04
−73 47	171 23	Terror.	10	−65 41
−74 26	168 37	Terror.	6	−68 40
−74 39	169 00	Erebus.	7	−69 47
−74 51	168 10	Terror.	4	−70 52
−74 46	168 42	Erebus.	10	−71 08
−74 46	167 53	Erebus.	2	−74 48
		− 75° to − 85°.		
−76 40	188 40	Erebus.	5	−77 53
−76 57	186 38	Erebus.	9	−81 33
−77 18	192 38	Erebus.	13	−81 50
−77 08	189 02	Erebus	6	−82 09
−77 11	192 58	Erebus.	6	−82 26
−77 22	188 43	Erebus.	12	−82 29
−77 07	192 22	Terror.	13	−83 03
−76 57	188 30	Terror.	9	−83 24
−77 17	191 35	Erebus.	6	−83 56
−75 39	168 33	Erebus.	9	−84 58

Lat.	Long.	Ship.	No. of observations.	Declination.
° ′	° ′			° ′
		− 85° to − 95°.		
−77 04	188 28	Terror.	5	− 85 09
−76 23	177 25	Erebus.	2	− 85 10
−77 12	187 02	Erebus.	10	− 87 29
−76 25	177 35	Terror.	2	− 88 55
−77 22	186 21	Erebus.	6	− 89 19
−75 36	167 45	Terror.	2	− 89 32
−77 03	186 40	Terror.	10	− 89 37
−77 28	186 33	Erebus.	6	− 90 21
−75 28	168 12	Terror.	9	− 90 44
−77 09	188 22	Erebus.	9	− 91 07
−77 35	186 40	Erebus.	9	− 93 22
−77 36	186 41	Terror.	9	− 93 24
−77 44	188 00	Erebus.	8	− 93 41
−77 54	188 27	Erebus.	8	− 93 41
−77 51	191 01	Erebus.	5	− 93 43
−77 46	186 53	Erebus.	8	− 94 14
−75 52	167 00	Erebus.	8	− 94 27
−77 51	189 42	Terror.	7	− 94 42
−77 45	189 00	Terror.	6	− 94 59
		− 95° to − 105°.		
−77 43	187 04	Terror.	8	− 95 21
−77 49	187 26	Erebus.	6	− 95 52
−77 51	187 38	Erebus.	6	− 96 00
−77 51	186 38	Erebus.	10	− 96 14
−77 47	180 34	Erebus.	1	− 96 17
−77 44	186 06	Terror.	5	− 97 11
−76 07	168 45	Erebus.	4	− 98 45
−75 58	168 50	Terror.	2	− 99 41
−76 10	166 02	Erebns.	4	− 99 41
−76 04	166 19	Terror.	5	−100 14
−77 47	176 19	Terror.	5	−102 09
−77 41	175 57	Erebus.	7	−104 25
		− 105° to − 115°.		
−77 50	178 00	Erebus.	4	−105 21
−76 22	165 44	Erebus.	6	−106 13
−76 47	169 26	Terror.	2	−107 05
−76 32	166 30	Terror.	9	−111 44
−76 36	166 18	Erebus.	13	−113 23
−76 33	164 45	Erebus.	8	−113 41
−77 22	172 04	Terror.	4	−114 21

Total number of observations 1368. No observation has been omitted or its result rejected. The scale of the declination chart has not permitted the insertion of all the results comprised in this table, and a few of those of the Terror have consequently been omitted in the very high latitudes where the figures are most crowded. The next number of these contributions, embracing the observations of the succeeding voyage, will contain a declination chart of the high latitudes on a more extended scale, in which all the results of both voyages will be inserted.

General Table of the Inclinations observed in Her Majesty's Ship Erebus, from June 1840 to April 1841.

Lat.	Long.	No. of observations.	Inclination.	Lat.	Long.	No. of observations.	Inclination.
° ′	° ′		° ′	° ′	° ′		° ′
−48 41	68 54	9	−70 00 *a*	−68 17	175 00	5	−83 12
−48 29	76 55	2	−70 55	−68 32	175 49	6	−83 28
−48 17	80 15	2	−71 50	−68 28	176 31	5	−83 17
−47 55	83 00	2	−72 34	−68 28	176 32	5	−83 35 *e*
−47 46	86 18	2	−73 33	−68 53	176 23	5	−83 40
−47 12	89 45	2	−73 35	−70 23	174 50	4	−85 00
−47 03	93 00	2	−74 37	−71 15	171 15	4	−85 50
−47 39	102 42	2	−74 28	−71 24	170 44	4	−85 53
−47 35	106 26	2	−74 31	−71 47	170 52	3	−86 10
−47 45	110 39	2	−75 08	−72 07	172 19	4	−86 13
−47 34	114 15	2	−75 26	−71 52	172 08	2	−85 53
−47 41	121 30	2	−76 04	−71 55	171 51	4	−85 55
−47 34	124 43	2	−76 40	−72 12	172 13	4	−86 41
−46 44	128 26	2	−75 41	−72 09	173 35	3	−86 03
−46 13	132 00	2	−75 17	−72 57	176 06	5	−86 11
−45 59	135 38	2	−73 48	−72 35	173 34	4	−86 36
−45 17	139 19	2	−73 23	−72 31	173 39	4	−86 51
−44 24	141 39	2	−72 37	−73 48	171 47	7	−87 04
−44 16	142 38	2	−73 03	−74 06	170 40	8	−87 12
−42 52	147 24		−70 38 *b*	−73 56	171 35	8	−87 11
−44 16	149 29	3	−70 41	−74 33	173 23	7	−87 29
−45 13	151 57	3	−71 49	−74 43	169 48	5	−87 25
−45 33	152 45	3	−71 37	−74 45	168 23	4	−88 18
−46 18	154 30	3	−72 04	−74 55	169 01	3	−88 21
−47 46	157 40	3	−73 14	−75 22	168 48	4	−88 36
−49 20	160 13	3	−74 15	−76 06	168 11	4	−88 27
−50 28	164 09	3	−74 23	−77 07	169 56	2	−88 01
−50 33	166 19		−73 10 *c*	−77 47	175 43	4	−86 48
−52 34	169 10	7	−73 52 *d*	−77 41	180 54	2	−85 54
−54 06	169 09	4	−74 46	−77 06	189 08	5	−85 56
−55 50	170 06	3	−76 16	−77 05	188 36	5	−86 12
−57 15	170 40	3	−77 43	−77 09	188 15	4	−86 23
−57 54	170 25	3	−77 51	−77 49	186 30	5	−86 10
−58 57	170 57	4	−78 04	−77 17	185 26	4	−86 49
−59 43	169 39	6	−78 34	−77 00	192 18	5	−85 36
−60 19	170 20	7	−78 53	−77 07	192 26	4	−85 26
−60 46	170 44	4	−79 06	−77 24	192 56	4	−85 45
−61 34	170 40	3	−79 30	−77 10	192 48	5	−86 06
−62 06	172 51	4	−79 41	−77 09	188 43	6	−85 54
−62 40	173 40	1	−79 58	−76 59	186 39	5	−86 23
−62 44	174 36	5	−80 09	−77 43	187 10	5	−85 51
−64 00	172 44	4	−81 03	−77 55	189 04	2	−85 49
−64 06	172 38	5	−81 03	−77 38	187 00	5	−86 19
−64 31	172 57	6	−81 11	−76 22	188 05	4	−86 07
−65 58	172 47	4	−82 20	−76 50	183 26	3	−86 23
−66 17	170 57	4	−82 25	−76 17	175 37	6	−87 15
−66 30	169 13	4	−82 40	−76 14	172 35	1	−87 36
−66 32	169 45	4	−82 31	−76 06	168 07	7	−88 21
−66 23	170 12	4	−82 53	−76 20	165 32	4	−88 35
−65 39	170 44	4	−81 51	−76 36	164 38	5	−88 19
−65 22	172 40	4	−81 43	−75 21	168 06	6	−87 52
−66 55	174 31	3	−82 13	−72 13	171 04	4	−86 23
−67 27	174 51	4	−82 58	−70 55	168 43	3	−85 53

a On shore at Kerguelen Island. *b* On shore at Van Diemen Island. *c* On shore at Auckland Island. *d*. On shore at Campbell Island. *e* On Ice.

General Table of Inclination. (Continued.)

Lat.	Long.	No. of observa-tions.	Inclination.	Lat.	Long.	No. of observa-tions.	Inclination.
° ′	° ′		° ′	° ′	° ′		° ′
−70 41	167 20	4	−85 51	−65 14	144 37	3	−85 05
−70 17	167 24	6	−86 19	−65 11	143 52	3	−85 10
−70 14	167 16	3	−86 06	−65 09	143 07	6	−85 16
−69 57	167 52	2	−85 41	−64 20	140 40	5	−84 36
−69 24	167 55	5	−85 28	−63 09	139 28	7	−84 46
−69 46	167 43	5	−85 54	−62 18	136 40	6	−84 20
−69 06	167 43	5	−85 26	−61 18	134 02	5	−83 55
−68 28	168 10	5	−85 07	−60 20	131 21	5	−83 31
−67 47	167 22	5	−84 28	−59 25	130 14	5	−82 52
−65 49	166 12	7	−83 35	−58 06	128 43	1	−82 09
−65 53	162 14	3	−83 51	−57 22	127 37	2	−81 43
−64 41	162 34	4	−82 55	−56 28	129 57	1	−80 43
−64 20	163 29	4	−82 54	−55 02	131 48	5	−80 15
−63 52	160 55	5	−83 32	−54 55	132 50	6	−80 07
−62 41	156 59	5	−82 33	−54 02	134 59	8	−79 39
−63 50	156 06	4	−83 54	−53 13	135 18	5	−79 09
−64 12	154 47	3	−84 06	−51 16	136 50	4	−77 59
−64 13	154 03	3	−84 06	−48 48	138 34	4	−76 54
−64 20	153 02	5	−84 14	−46 55	139 55	3	−75 42
−63 54	151 56	3	−84 06	−46 25	140 55	7	−75 12
−64 18	149 09	3	−84 48	−44 57	144 18	8	−73 54
−64 33	148 03	4	−85 03	−43 50	146 00	5	−72 15

General Table of the Intensity of the Magnetic Force from the observations made on board Her Majesty's Ship Erebus, between July 1840 and April 1841.

Latitude.	Longitude.	Intensity. London = 1·372.	Latitude.	Longitude.	Intensity. London = 1·372.	Latitude.	Longitude.	Intensity. London = 1·372.
° ′	° ′		° ′	° ′		° ′	° ′	
−48 41	68 54	1·465	−60 31	170 32	1·951	−77 00	192 18	2·039
−48 29	76 55	1·539	−61 17	171 14	1·960	−77 10	192 48	2·036
−48 17	80 15	1·574	−62 40	174 40	1·983	−77 14	192 02	2·020
−47 55	83 51	1·601	−64 00	172 44	1·976	−77 09	188 50	2·036
−47 46	86 18	1·575	−64 06	172 38	1·973	−76 58	188 40	2·035
−47 12	89 45	1·565	−64 31	172 55	1·988	−77 43	187 11	2·035
−47 03	93 00	1·712	−65 46	171 40	1·996	−76 55	188 49	2·048
−47 26	99 54	1·783	−66 31	169 20	2·008	−76 50	183 26	2·035
−47 35	106 26	1·863	−66 23	170 12	2·018	−76 16	175 50	2·017
−47 40	112 27	1·898	−65 39	170 44	2·046	−76 03	169 30	2·033
−47 41	121 30	1·992	−65 22	170 40	2·025	−76 20	165 32	2·041
−47 34	124 43	1·996	−66 55	174 31	2·009	−75 03	168 44	2·040
−46 28	130 13	2·007	−68 30	175 40	2·011	−71 17	170 43	2·037
−45 59	135 38	1·989	−68 28	176 31	2·032	−71 04	170 07	2·026
−45 17	139 19	2·005	−68 28	176 32	2·025	−70 25	167 27	2·036
−44 24	141 39	1·976	−68 48	176 45	2·016	−69 24	167 49	2·025
−44 16	142 38	1·934	−70 23	174 50	2·033	−68 28	168 10	2·047
−45 02	143 10	1·923	−71 15	171 15	2·030	−67 52	167 28	2·043
−46 22	141 06	1·954	−71 24	170 44	2·029	−65 31	167 42	2·041
−46 29	140 40	1·949	−71 47	170 52	2·056	−64 58	162 27	2·024
−43 41	146 03	1·892	−72 07	172 19	2·038	−64 13	163 18	2·018
−42 52	147 24	1·820	−71 55	171 51	2·028	−63 57	161 11	2·010
−44 10	149 29	1·844	−72 12	172 13	2·032	−62 41	156 59	2·022
−45 13	151 57	1·833	−72 09	173 35	2·026	−63 50	156 06	2·013
−45 33	152 45	1·843	−72 57	176 06	2·038	−64 13	154 03	2·011
−46 18	154 30	1·820	−72 35	173 34	2·035	−64 20	153 02	2·032
−47 46	157 40	1·817	−72 31	173 39	2·039	−63 54	151 56	2·023
−49 20	160 13	1·846	−73 47	171 50	2·052	−64 26	148 20	2·065
−50 28	164 09	1·858	−74 10	170 28	2·044	−64 45	142 00	2·068
−50 33	166 19	1·851	−74 06	171 20	2·052	−63 09	139 28	2·043
−52 42	169 10	1·877	−73 56	172 20	2·035	−61 46	135 12	2·051
−53 47	169 02	1·844	−74 36	173 01	2·037	−60 19	131 20	2·071
−54 25	169 16	1·874	−74 44	169 43	2·045	−58 00	128 40	2·056
−55 50	170 06	1·903	−75 22	168 48	2·048	−54 44	132 21	2·027
−57 15	170 40	1·914	−76 06	168 11	2·031	−53 13	135 18	2·047
−57 54	170 25	1·911	−76 46	169 22	2·040	−51 16	136 50	2·041
−58 57	170 57	1·920	−77 47	175 43	2·017			
−59 41	169 38	1·932	−77 04	188 24	2·017			
−60 14	170 15	1·951	−77 17	185 26	2·023			

XI. *On the Organ of Hearing in Crustacea.* By Arthur Farre, *M.D.*, *F.R.S.*

Received June 15,—Read June 15, 1843.

Although the existence of an organ of hearing in the class Crustacea has not altogether escaped the observation of anatomists, yet the descriptions which have been hitherto given of that structure have stopped short at the point where the interest of the subject begins. For while some general analogies have been traced between its more prominent and obvious parts, and those of the organ of hearing in other classes, the essential features in this remarkable piece of mechanism, as developed by the aid of the microscope, have been quite overlooked. It is my object to supply this deficiency in the following account of some dissections which were commenced many years ago, when my attention was more particularly directed to comparative anatomy.

But first it is important to point out an error which has arisen from the confusion of two separate and distinct organs situated, the one at the base of the larger or second pair of antennæ, and the other at the base of the smaller or first pair, to each of which the function of an organ of hearing has been assigned by different anatomists.

With regard to the organ situated at the base of the great antennæ, which is certainly not the organ of hearing, I have little of observation to offer. This organ in the Lobster (*Astacus marinus*), which affords a familiar example, is situated on the under surface of the base of the great antennæ on either side (Plate I. fig. 1. *a a.*), and consists of a small and slightly conical papilla, abruptly truncated, and having stretched over it a membrane, in the centre of which is an aperture capable of admitting a small bristle, the level of the membrane being somewhat sunk below the margin of the papilla, which forms a slightly elevated ring around it. On making a section of this part, nothing more is discovered than a narrow canal in the fleshy substance, leading perpendicularly from the external orifice, and terminating abruptly at the depth of two lines; neither the canal nor the adjacent parts exhibit anything remarkable in their structure. A distinct nerve however is sent off to this organ from the supra-œsophageal ganglion, taking its origin immediately behind that of the greater antennal nerve, and pursuing its course long and slender until it arrives immediately beneath the papilla, where it becomes lost, Plate IX. fig. 10. *e e*, fig. 11. *d*.

A similar organ exists in the river Cray-fish (*Astacus fluviatilis*), but in this instance instead of a narrow canal, the part swells out into a small membranous chamber, still however destitute of anything remarkable in its structure, except that

the mouth of this little sac, immediately beneath the external orifice, is of a slightly horny substance and dark brown colour. A bristle may be easily passed into the orifice, as in the preceding species, Pl. X. fig. 17.

I feel that any explanation that might be offered as to the use of this organ would be little better than conjecture, since there is nothing in the structure of the parts to lead to any definite conclusion; but there are one or two points which may be noted as peculiar.

The organ is situated not far from the mouth, and is directed downwards. It appears to be supplied by a separate nerve sent off from the supra-œsophageal ganglion, and I have ascertained, by repeated experiments, that it is the most sensitive part of the body; since, while the mechanical irritation of any other parts excited only a slight movement in the limbs of the animal, when out of water, and somewhat feeble, the touching of this part was immediately followed by a violent and almost spasmodic flapping of the tail. These circumstances, together with the situation of the organ, appear to point it out as intended possibly for the purpose of testing the quality of the food; as in fact an organ of smell, evidently endowed with an exquisite sensibility; but in the absence of other analogies I would be understood as offering this rather as a conjecture, subject to correction by further examination and experiment. I may add, that I have not observed this organ in any other than the two species just noticed.

But it is to the true organ of hearing that I would more particularly direct attention. This remarkable organ is situated in the base or first joint of the lesser pair of antennæ, the joint being slightly dilated at its base, Pl. IX. fig. 2. *a*.

Its precise seat is indicated externally by a tough membrane, covering an oval aperture in the upper surface of this joint, Pl. IX. fig. 2. *b*. The membrane appears to be a continuation of the same structure which forms the shell, but in which the earthy matter is wanting.

Towards the inner and anterior margin of this membrane, there exists a small round aperture into which a bristle can be easily passed, Pl. IX. fig. 3. This orifice is capable of being dilated into a slit-like aperture, which in some specimens appears to be facilitated by the detachment of a small flap of the calcareous shell, and the interposition of a portion of membrane between it and the body of the joints, so as to constitute a small valve at this part, by which the aperture is capable of being enlarged (fig. 3. *a*.).

On removing this oval membrane, together with a portion of the surrounding shell, the internal organ is brought into view, completely imbedded in the soft integument and muscular structure of the antennæ. By careful dissection these parts are easily removed, and the organ is seen suspended in the centre of the joint, being free on all sides, and having a single attachment at the inner and anterior angle around the margin of the aperture just noticed, Pl. IX. fig. 4.

This organ, the vestibular sac, nearly fills the cavity of the joint. It is shaped

somewhat like an auricle, is more convex in its outer than its inner margin, and terminates below in a slight appendix. It is of a delicate horny structure, of the consistence of thin quill, and is nearly transparent, so as to admit of its contents being seen through the parietes.

On removing a portion of the upper surface so as freely to expose the cavity, a number of minute particles of siliceous sand are found lying at the bottom, Pl. IX. figs. 5 and 6. In the first specimens which I examined, the presence of these appeared to be accidental; but as on pushing the inquiry further I invariably found them, not only in this species, but in every other in which the organ existed, I began to regard them as constituting essential parts of the structure; as in fact, subsidiary otolithes derived from without, and supplying the place of these calcareous bodies which are found in various classes as a permanent portion of the auditory apparatus. These particles, no doubt, gain admission by the aperture just noticed, and as they are of nearly uniform size, or at least not exceeding a certain size, the largest being about $\frac{1}{100}$th of inch in diameter, the slight valve at the aperture may be regarded as serving the purpose of a regulator, while the water would be allowed to flow freely at all times by the circular opening. The margin of this aperture is surrounded internally by a *chevaux de frise* of hairs, Pl. IX. fig. 7. *a*. These are pointed forwards, and may be there placed either for the purpose of preventing the ingress of soft or flocculent particles with which the cavity might become clogged, or for regulating the admission of the particles of sand into the cavity.

Along the lower surface of the vestibular sac is seen running a semicircular line, broader at its upper than its lower extremity. This part is more easily examined after the sand has been washed away by agitation under water, Pl. IX. figs. 6 and 7. *b*. It is then seen, with a power of 18-linear, to consist of several rows of ciliated processes, of which one row is more regular and prominent than the rest, and crests the entire margin of the ridge. The processes diminish in size and number on either side, and are in some places seen in groups, but always assume the general form represented in fig. 7.

With a power of from 100 to 200 linear these processes are seen to be hollow, and to be covered with a fine down of hairs of exquisite delicacy, while in their interior are contained numerous minute granules which are apparently nerve-granules, Pl. IX. fig. 8. These processes are inflated at their base, so as to form a globular swelling, where they are articulated to corresponding circular apertures in the walls of the sac from which they spring.

Immediately beneath this crescentic arrangement of processes lies the plexus of the auditory nerve, filling up a slight groove upon the under surface of the sac. The auditory nerve has a separate and distinct origin from the supra-œsophageal ganglion. It arises by two delicate branches between the lesser and greater antennal nerves, and proceeds directly upwards and outwards to reach the under surface of the vestibular sac, Pl. IX. fig. 10. *c c*. Here it expands into a plexus, covering the whole

of the under surface of the sac, and spreading round towards the upper surface, where it becomes thinner and is gradually lost. On the under surface, however, the several fibres forming the plexus are easily seen even by the naked eye; but they require great delicacy of manipulation in their dissection, as the plexus is imbedded in the soft fleshy substance of the joint, and cannot be fairly exposed until this has been picked away grain by grain. On this account, and also from the readiness with which the tegument is detached from the shell in Crustacea, it would be impossible to trace any nerve-filaments into the hair-like processes, even should they extend so far. They may, however, be traced as forming a considerable plexus up to their very base, and being most abundant where the processes are principally situated, while the centre of the processes is found to be occupied by granules having every appearance of nerve-granules, and which are probably derived from the plexus lying immediately beneath them. The antennal nerve (Plate IX. fig. 10. *b.*), which passes through this joint along the inner and under side of the sac to supply the rest of the antenna, sends off two or three minute filaments to this plexus, probably for the purpose of supplying the contiguous fleshy substance.

Before I proceed to offer a few brief suggestions as to the use of their several parts, it may be well to state how far I have found this structure constant in the class Crustacea.

In the river Cray-fish (*Astacus fluviatilis*) all the parts that are found in the Lobster exist, with the exception of the fenestra ovalis and its membrane, which appear to be peculiar to the latter, as I have not found them in any other species. The parietes of the joint are, however, rather thinner and more flexible in their situation, although a distinct membrane is wanting.

The vestibular sac in this species is nearly hemispherical in form, having the convex surface directed upwards and the plane surface downwards, Plate X. figs. 12, 13, 14. *a.* Upon the plane surface are situated several rows of hairs, as in the former species; the same disposition to a crescentic arrangement is observed, but the row of processes in this species forms rather more than the half of a circle (figs. 13, 14, 15. *a.*). The mode in which they are disposed is readily seen upon the under, or flat surface, before the sac is opened, where their seat is indicated by a row of minute pores of great regularity, the processes with which they communicate being seen through the transparent parietes springing from the margin of the pores and projecting into the cavity of the sac.

The sac is here also filled with minute particles of siliceous sand, which in the specimen that I examined were so numerous as to fill about one-third of the chamber.

The processes are more delicate than in any other species; they are sharply pointed at their extremity, and swell out broad towards the base, where they contract again; they are also somewhat flattened and have a single row of hairs on either side, extending only about half-way down their length (fig. 16.).

A valvular orifice (Plate X. fig. 11. *b.*) upon the upper surface of the joint containing the organ leads to the interior of the sac. This orifice is guarded internally by a double group of processes (fig. 15. *b.*) projecting forwards towards the aperture, as in the Lobster.

This species is so small that the examination and dissection of the parts require great delicacy in handling them, as is also the case with the next species. All these dissections require to be made under water.

In the Hermit Crab (*Pagurus streblonyx*) the form of the vestibular sac differs again from both the preceding species. It is somewhat cordate, having the base attached near the external orifice and the apex projecting backwards, as in the Lobster, Plate X. figs. 5, 6, 7.

The processes are not so regularly arranged in this as in the former genus, they are also shorter and more pubescent, Plate X. figs. 8, 9, 10. In all other respects the organ resembles those already described, having the same valvular aperture (fig. 3. *a.*) leading into the sac, the same arrangement of hairy processes guarding this orifice (figs. 7, 8. *a.*), and the same siliceous particles in the cavity of the sac (fig. 8. *b.*).

In *Palinurus* there is an obvious degeneration with regard to the auditory apparatus, agreeing perhaps with the comparatively rude form and less perfect endowments of this genus. The organ also is far smaller in proportion to the size of the animal than in other genera.

The vestibular sac forms here a small lappet (Plate X. fig. 19. *a.*) of a tough leathery consistence, hanging into the interior of the joint of the antenna, of which it occupies but a small portion (fig. 19.). The sac is not transparent, and the processes are few in number and arranged with little regularity (figs. 20, 21.). The siliceous particles are of larger size (fig. 20.), and the aperture (fig. 18. *a.*) proportionally large and free, and its situation more prominently marked externally than in other genera.

These dissections will suffice to show that there exists in several genera of the class Crustacea an organ of hearing of very delicate conformation and remarkable uniformity of type. How far the existence of this organ may be general throughout the class I have not had opportunity to determine. It certainly does not belong to all the Macrourous genera, as no trace of it is to be found in Squilla; nor have I found it in any of the Brachourous decapods, but of these I have examined only one or two species.

We recognise, however, in this structure all the essential parts of an organ of hearing in its primitive form; a distinct acoustic nerve from the supra-œsophageal ganglion, terminating in a plexus which is expanded upon a vestibular sac. In this sac nature seems to hint at the formation of a cochlea in the little twisted appendix so distinctly visible both in *Astacus marinus* and in *Pagurus*, Plate IX. figs. 5 and 6, Plate II. figs. 5, 6. These parts, constituting a membranous labyrinth, are surrounded and protected by an external case, in which anatomists have already traced the type

of an osseous labyrinth with its fenestra ovalis and membrane, while, as in other primitive forms of the organ of hearing, no trace exists of either semicircular canals, tympanic cavity and ossicula, or external concha.

There are, however, some features now described in respect of which the organ differs from any other form with which we are acquainted, viz. in the remarkable apparatus in which the auditory nerve terminates, and in the singular substitute for otolithes found so constantly in the vestibular sac. With regard to the termination of the acoustic nerve, I have shown that the plexus into which it divides closely surrounds the vestibular sac, but is most extensively developed immediately beneath the row of processes lining the cavity, and is lodged in a slight depression or groove from the crest or opposite surface of which they spring. It is easy to observe the row of apertures by which this part of the sac is pierced, each pore leading into the central cavity of a process, and each process filled with granules of apparently nerve matter, loosely contained in the interior of the process, and which escapes when it is detached or torn, Plate IX. fig. 8. The water, which is freely admitted into the vestibular sac by the aperture in its upper part, supplies the place of an ento-lymph, and constitutes perhaps the only example of an organ of hearing in which the same fluid by which the vibrations are communicated, is received directly into the chamber upon which the acoustic nerve is expanded.

The grains of sand appear to supply the place of otolithes; and in reference to this, which is not the least remarkable feature in the construction of the organ, it may be observed that the grains appear to consist almost entirely of particles of siliceous sand, and are certainly not cretaceous bodies secreted by the organ itself. They are transparent and angular, and are unaffected by acids. I have observed also that their size is not greater than would allow of their entering by the valvular aperture; and that in those species where the aperture is large and free, as in Palinurus, the grains are coarse in proportion, while in the other species, where the valve is closer, they are correspondingly fine. The circumstance of a natural structure being supplied by artificial means is not without its parallel in the animal kingdom, and can hardly fail to suggest the familiar example of the stomach of granivorous birds, into which stones are taken for the purpose of supplying the office of gastric teeth, and become essential to the due performance of the function of that organ.

Such being the nature of the apparatus, little of explanation appears to be required with regard to the function of its several parts.

The fact of the delicate nerve having a separate origin from the supra-œsophageal ganglion, and being distributed in the form of a plexus around the sac, seems to proclaim this a nerve of special sense, more particularly as the lesser antennal nerve passes so close to the sac in its course through the antenna (Plate IX. fig. 10. *b.*) that for ordinary purposes the sac might have been most readily supplied from it. To this sac, however, the antennal nerve sends off only one or two delicate twigs, and those apparently for the purpose of supplying the tegument or muscles immediately

surrounding the sac, and thus increasing the analogy between this and the portio dura and mollis of the seventh pair of nerves in the higher Vertebrata.

Next, the remarkable arrangement of ciliated processes immediately overlying this plexus, with each process filled with nerve granules, exhibits an apparatus for extending the extremities of the nerves in such a manner as to render them sensitive to the most delicate vibration of the fluid with which the sac is filled. But to heighten the effect of this the grains of sand are added, thus forming adventitious otolithes, which, moving freely in the fluid contents of the sac, would considerably increase the vibration of that fluid.

But it is probable that the nerves are also more powerfully affected by the immediate contact of the stony particles themselves, since if they were only added for the purpose of multiplying the vibration, these would still have been rendered appreciable by the simple expansion of the plexus around the sac, without the necessity for a more complex apparatus. But the fact that the ciliated processes are always arranged upon that part of the surface of the sac which in the usual position of the animal would be lowest, so that the stones would by gravitation be constantly in contact with or near to them, seems to point to the immediate contact of these two parts as a condition essential to the performance of the functions of the organ. Thus the least vibration in the fluid would throw one or more of the particles into contact with one or more ciliated processes. And in consideration of the number of these particles and the readiness with which they would move in the fluid, and further of the extent of the ciliated surface and the delicate and abundant pubescence with which each process is clothed, it would seem hardly possible that the slightest vibration could occur in that fluid without throwing a particle of sand into contact with one of the processes, and thus causing the vibration to be conveyed to the nerve at its base.

Now the mode in which vibration may be excited in the fluid is two-fold. The membrane expanded upon the upper surface of the joint containing the sac, would receive the vibrations and transmit them to the sac through the medium of the intervening flesh, which would thus supply the place of a peri-lymph. And again, they would be transmitted from the parietes of the sac to the fluid contained within, while in those species in which there is no fenestra and no membrane, the vibrations could only be communicated through the general surface of the parietes; as is the case for example in Cephalopods and fishes which have no external membrane.

But further, the seat of this organ being a portion of the antenna, seems to connect the exercise of its function in some degree at least with the office of the antenna; for it is obvious that the latter could not be brought into play without causing in the fluid contents of the sac, an agitation similar to that which would be produced by the undulations of the surrounding fluid striking upon the membrane, or the parietes of the antenna, and exciting corresponding undulations within.

In this view of the matter, it would seem that the attributes of this organ are capable of being called forth by the exercise of the same mechanism as that which is furnished for the purpose of supplying the animal with its most delicate sense of

touch, namely the antenna. And it is remarkable that the organ of hearing, as thus constituted, seems to be in its essential features no other than a delicate series of antennæ, for the very form of the antenna with its marginal fringe of hairs is repeated in the ciliated processes of the internal organ, but with this difference, that the latter are infinitely more minute, and therefore adapted to receive vibrations so delicate as to be inappreciable to the former.

I feel that to carry the argument further would be to enter the region of speculation in regard to the precise nature of the sense to which this organ is appropriated. I have rather assumed, in common with others, that its office is that of *ordinary hearing*, from the close analogies which it presents with the elementary forms of that organ in other classes, and also from the generally received opinion that the Crustacea are highly sensitive of sound. But it is obvious that, if an organ of hearing, it constitutes at the same time but a repetition, upon a most refined scale, of the form of an organ of touch; and it is difficult to refrain from hazarding a conjecture that a more extended and minute observation of the apparatus of the senses in different classes of the animal kingdom might develope other structures in which a similar approximation is made in their essential forms, as well as in the mode in which they are impressed by external agents; and that while, as in this instance, an organism devoted to one sense may constitute but a repetition on a more refined and delicate scale of that of some other, the difference between the nature of the senses themselves may not be greater than is measured by this degree of approximation, and that the essential difference between their several organs may be found to lie in the degree of delicacy with which they are capable of distinguishing the vibrations of the media by which the entire organism is surrounded.

The subject becomes more interesting in proportion as it is brought to bear upon the consideration of the means by which the descending series of animals, in whom the organs of sense become gradually diminished both in number and perfection of structure, until they appear to become merged in one single sense, are enabled to test the properties of surrounding objects. And the example therefore, as regards structure at least, of a kind of mixed sense, such as that now described, may it is hoped be not without its value in assisting us to arrive at a knowledge of the nature of the more obscure senses as enjoyed by the lower animals.

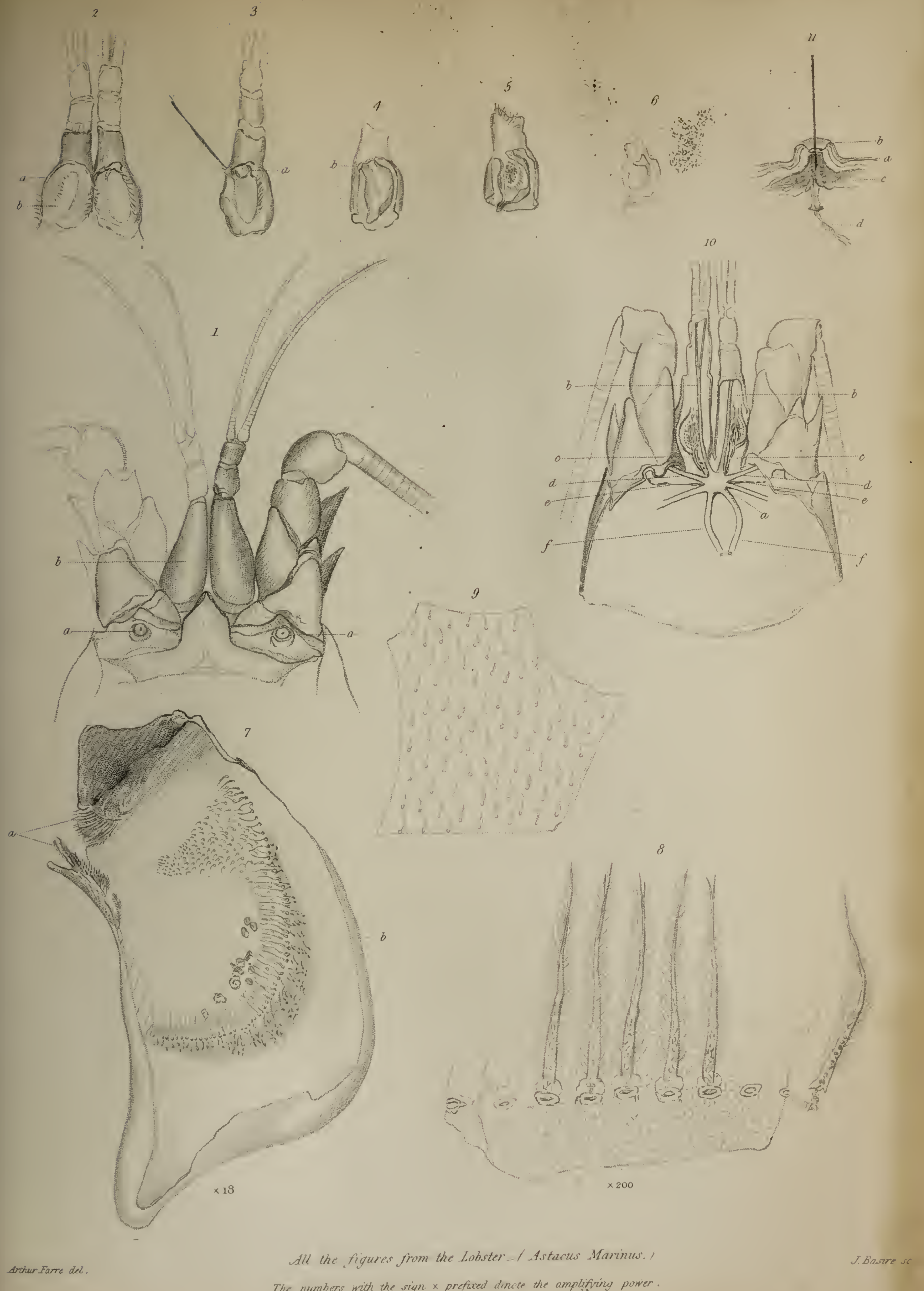
Explanation of the Plates.

PLATE IX.

Fig. 1. Anterior portion of the body of a Lobster (*Astacus marinus*) viewed from below.

a a. The organ (of smell?) situated at the base of the second pair of antennæ.

b. Dilated base of the first pair of antennæ containing the organ of hearing.



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All the figures from the Lobster. (Astacus Marinus.)

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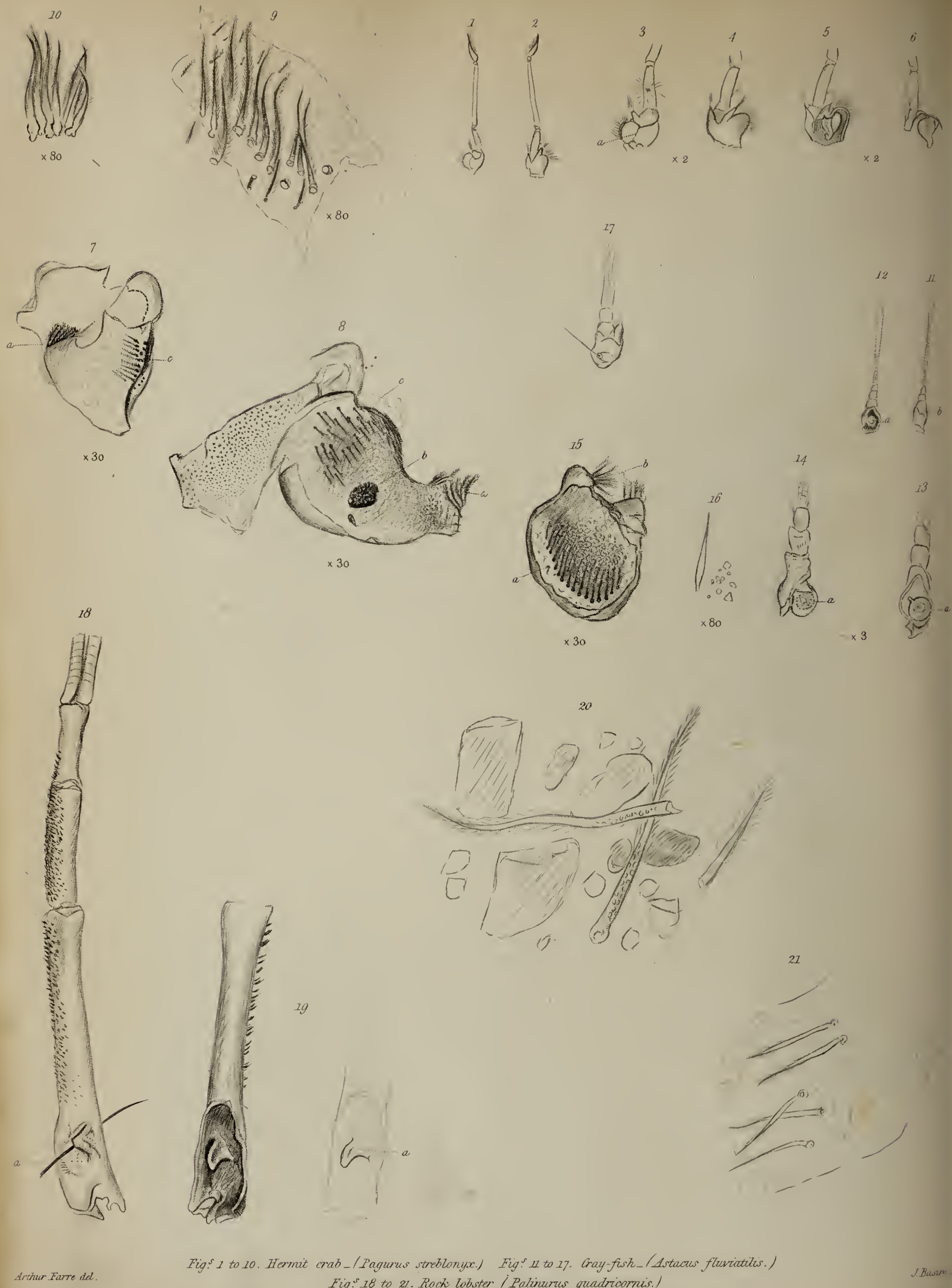
The numbers with the sign × prefixed dinote the amplifying power.



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Figs. 1 to 10. Hermit crab _ (Pagurus streblonyx.) Figs. 11 to 17. Cray-fish _ (Astacus fluviatilis.)
Figs. 18 to 21. Rock lobster (Palinurus quadricornis.)
The numbers with the sign × prefixed denote the amplifying power.

Fig. 2. Portions of the lesser or first pair of antennæ viewed from above, showing the fenestra ovalis and membrane covering it (*b*).

Fig. 3. Right antenna. A bristle is passed into the aperture which leads to the interior of the sac. The valvular portion is seen at *a*.

Fig. 4. The fenestra ovalis, with its membrane and a portion of the surrounding substance, have been removed, showing the vestibular sac immediately beneath. The surrounding flesh has also been removed. In this figure the aperture at the inner and upper angle is more distinctly seen (*b*).

Fig. 5. Upper portion of the vestibular sac removed, showing the interior of the cavity, with the crescentic arrangement of ciliated processes and grains of sand at the bottom.

Fig. 6. The same part removed, and the grains of sand washed out and lying by the side to give a clearer view of the interior.

Fig. 7. The same, showing the arrangement and form of the ciliated processes, both in the centre of the sac *b*, and at the orifice *a*. A few particles of sand are lying close to the hairs, the rest having been removed.

Fig. 8. Separate processes from the central row. The processes are covered with fine hairs, and some are bifid at their extremity. They contain granules of nervous matter. The processes are inflated at their base, where they are set on to corresponding apertures in the walls of the sac.

Fig. 9. Small processes covering other portions of the sac.

Fig. 10. View of the nervous system (the viscera having been removed) seen from below.

a. Supra-œsophageal ganglion.
b b. Nerves to first pair of antennæ.
c c. Acoustic nerves.
d d. Nerves to second pair of antennæ.
e e. Nerves to organ at its base (olfactory ?).
f f. Nervous collar surrounding œsophagus.

The optic nerve being deep-seated is not shown in this figure.

Fig. 11. The organ situated at the base of the great antennæ. A section has been made through the centre, perpendicularly.

a. Shell. *b*. Membrane covering the circular aperture and having a bristle passed through the opening in its centre. *c*. Fleshy lining of shell. *d*. Nerve.

(All the figures in this Plate are from the Lobster.)

PLATE X.

Fig. 1 to 10 from *Pagurus streblonyx*.

Fig. 1. Right antenna, upper surface.

Fig. 2. Right antenna, under surface.

Fig. 3 and 4. The same enlarged. The valve is seen at *a*, fig. 3.

Fig. 5. Portion of joint removed to show the vestibular sac.

Fig. 6. A further portion removed, showing the same more distinctly. The pores at the base of the processes are shown in this figure.

Fig. 7. The sac removed, showing the ciliated processes on the parietes *c* and near the orifice *a*.

Fig. 8. The same laid open. The letters refer to the same parts. *b*. Mass of sand.

Figs. 9 and 10. Groups of ciliated processes.

Figs. 11 to 17. *Astacus fluviatilis*.

Fig. 11. Right antenna, upper surface. *b*. Valve.

Fig. 12. The same laid open and viewed from below. *a*. Vestibular sac.

Figs. 13 and 14. The same. The crescentic row of orifices is seen in both figures.

Fig. 15. Vestibular sac laid open. Processes and sand at *a*. Processes at orifice *b*.

Fig. 16. Separate process and grains of sand.

Fig. 17. Olfactory (?) organ. A bristle passed into the orifice.

Figs. 18 to 21. *Palinurus quadricornis*.

Fig. 18. Antenna, showing external orifice, into which a bristle is passed, *a*.

Fig. 19 *a*. Vestibular sac.

Fig. 20. Detached ciliated processes and grains of sand.

Fig. 21. Processes in walls of sac.

VIII. *On the Structure, Relations, and Development of the Nervous and Circulatory Systems; and on the Existence of a Complete Circulation of the Blood in Vessels, in Myriapoda and Macrourous Arachnida.—First Series. By* George Newport, *Esq., President of the Entomological Society of London, and Member of the Royal College of Surgeons, Corresponding Member of the Philomathic Society of Paris. Communicated by* P. M. Roget, *M.D., Sec. R.S. &c.*

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THE increasing importance that is daily attached to the study of the comparative anatomy of the Invertebrata, and the interest with which every microscopic examination of structure is now regarded, as assisting to elucidate the great problems of life in the higher animals, have encouraged me through several years to prosecute a series of investigations, in the articulated classes, on two of the most important portions of the body,—the nervous and circulatory systems. These investigations have afforded me, from time to time, some interesting results, part of which, on one of these structures, I have already had the honour of communicating to the Royal Society. I now propose to communicate the results of my examinations of both these structures, and to illustrate their development, and the relations which they bear to each other, in some of the principal classes, commencing, in the present paper, with the Myriapoda and Arachnida.

The objects to which my attention has been directed in this paper are three:—*First,* the minute anatomy of the nervous system in the Myriapoda and Macrourous Arachnida, more especially with regard to the structure of the cord and its ganglia, and the means which these afford us of explaining the physiology of the nervous system, and the phenomena of the reflected movements in articulated animals. *Secondly,* to demonstrate the existence of a complete system of circulatory vessels in the Myriapoda and Arachnida. *Thirdly,* to show the identity of the laws that regulate the development of the nervous and circulatory systems in these Articulata, and their dependence on the changes which take place in the muscular and tegumentary structures of the body, as I formerly showed in regard to the changes in the nervous system of insects*.

1. Nervous System.—*Theory of Development.*

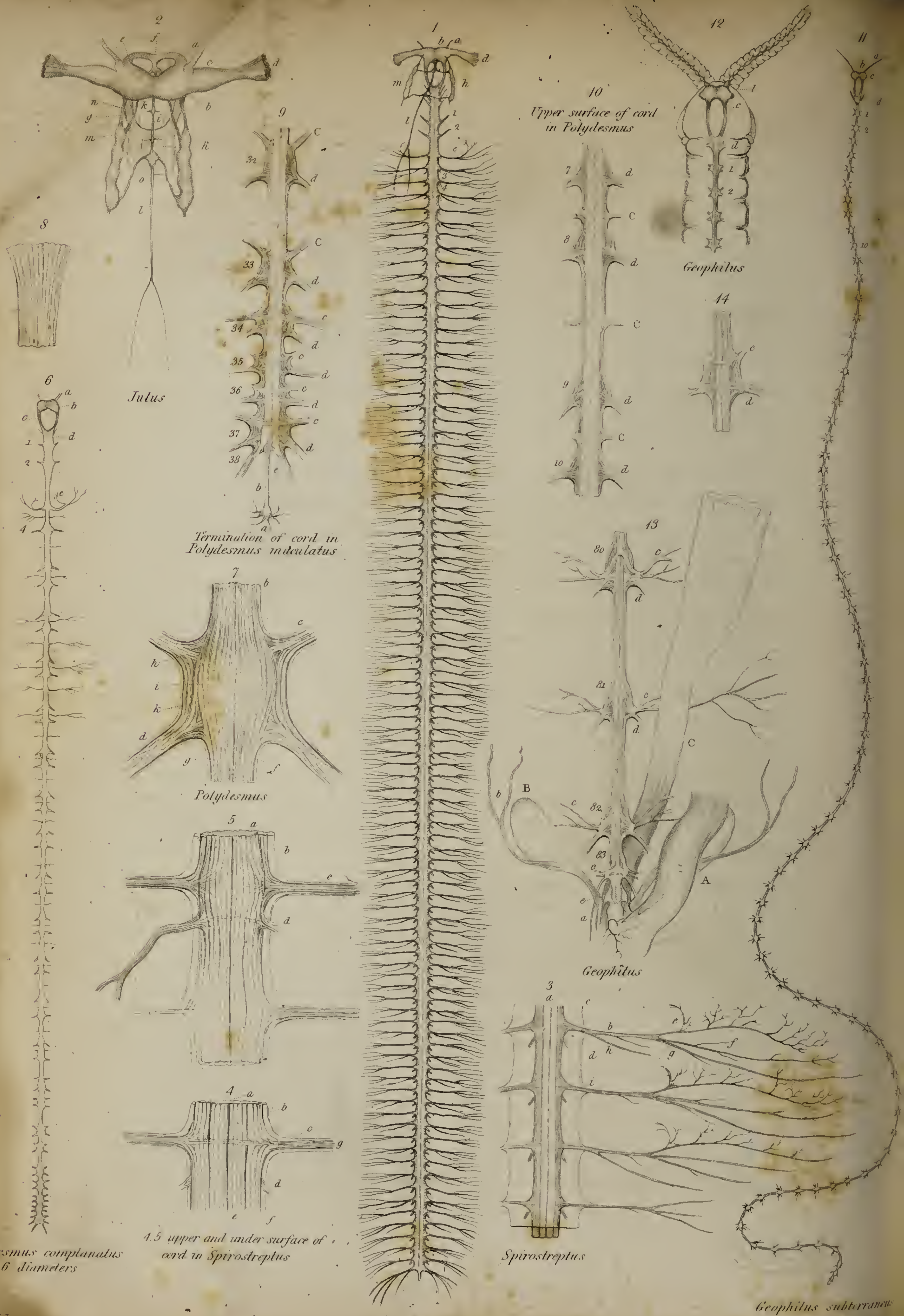
The nervous system of the Myriapoda approaches in the simplicity of its formation nearer to that of the Annelida than to any permanent condition in the higher Articulata, or even to its transitory state in the larvæ of insects. In the lowest types of the

* Philosophical Transactions, 1834.

orders *Chilopoda* and *Chilognatha*, the great divisions of the Myriapoda, it exhibits two marked conditions. In the Chilopoda it has the form of a double cord connected by large ganglia in each segment, as in most of the Annelida, Crustacea, and Insecta; but in the vermiform Chilognatha, which former researches* have proved to me are most nearly connected to the Annelida, the two parts of this double cord are so closely united laterally as to appear like a single cord, that gives off a multitude of small nervous trunks at its sides throughout its whole length, but without distinct ganglionic enlargements at their origin. The cord is, nevertheless, composed in each Order of two longitudinal portions, more or less closely approximated, and united at certain distances by ganglia. It is extended along the under surface of the body beneath the alimentary canal, and its ganglia correspond in number to the number of segments, in strict accordance with the character established by CUVIER in his definition of the subkingdom Articulata.

In all the Articulata two modes of development are in operation in the same animal; first that of *growth*, or simple extension and enlargement of each individual part; next that of *aggregation* of two or more parts to form particular divisions or regions of the body. This latter mode of development is carried to a greater extent in insects than in any other of the Invertebrata, and, as is well known, changes the animal from a simple, elongated, worm-like larva, furnished with many pairs of organs of locomotion, and composed of segments almost uniform in size and appearance, to an individual of a totally different character, with its body divided into three distinct regions, differing in size and appearance, and separated from each other, with the number of its organs of locomotion reduced, and those that remain greatly enlarged and altered. Some of these changes in the segments take place also in the Myriapoda, but are carried only to a very slight extent. The head is composed of several segments, either consolidated together like the head in true insects, as in the vegetable-feeding Chilognatha, or separated, and moveable on each other, to adapt them to the carnivorous habits of the species, as in the rapacious Chilopoda. In like manner each moveable division of the body is in reality composed of two distinct segments, originally separate, but anchylosed together at an early period of their formation. Each of these sub-segments ought, therefore, to possess its separate ganglion, and this in reality is the case. The *head* is composed of the elements of at least four segments, and perhaps even of six; and contains ganglia, placed two above and two below the œsophagus, which give nerves to the antennæ, to the eyes, to the maxillæ, and to the mandibles. The two anchylosed portions of each moveable segment of the body have, in like manner, their separate ganglia, as in the *Polydesmidæ*, in which the ganglia remain distinct throughout life in the posterior segments, but have coalesced in the anterior, more especially in those which are nearest to the head. These unions are occasioned by a reduplication inwards of the tegument, as in the aggregation of segments in insects, but this is carried to so slight an extent in the

* *Op. cit.*, Part II. 1841.



G. Newport del.

Myriapoda as hardly to affect the general form and appearance of the animal, although influencing every structure in that part of the body in which the change occurs.

Structure.—The brain of the Myriapod is formed by the aggregation of separate ganglia* placed above the œsophagus. The first pair of ganglia are always the smallest, and give origin on their front to the nerves of the antennæ, the anterior prolongations of the nervous cord. The second pair, immediately behind them, constitute, as in insects, the organs of volition, and represent the brain of Vertebrata. They are in reality, as I have elsewhere shown, the analogues of the *corpora quadrigemina*†, and give off nerves at their sides to the organs of special sense,—the eyes. They are always more developed than the ganglia of the antennæ, and continue to increase in importance as we ascend to the most perfectly developed insects. They are of large size, even when those of the antennæ are almost absent, as in the larvæ of lepidopterous insects, and even when the organs of vision are entirely wanting, as in the whole of an extensive family of Chilognatha,—the *Polydesmidœ*. They are placed transversely above the œsophagus in the form of a crescent, the side of each lobe being a little in advance of the posterior. They are connected on their under and external surface by two cords of nervous matter, which are prolonged downwards, one on each side of the pharynx, and constitute the *crura cerebri*,—with the united ganglia of the maxillæ and mandibles, which form the analogue of the *medulla oblongata*‡—the commencement of the abdominal cord.

In the *Iulidœ* (Plate XI. figs. 1 and 2) these cerebral lobes (*b*) are convex, both on their upper and posterior surfaces, and their original separation is marked by a median sulcus, which is more or less evident in different individuals. In some it is almost entirely obliterated, and the two lobes are more closely approximated, indicating, perhaps, the greater extent to which this important division of the nervous system has been developed in them than in others in which the union of the lobes is less perfect. Each lobe is connected externally with the *optic ganglion* (*c*), which is of an elongated, oval, and slightly conical form, from which nervous filaments radiate outwards and downwards in a triangular fasciculus to the cornea (*d*). The fibres are extended almost close to the cornea before they are clothed with dark pigment and form the retina, the chamber of each lens being scarcely longer than wide, so that the eyes are fitted only for examining near objects, a condition entirely in accordance with the habits of these animals. The ganglia of the antennæ (*a*) in Iulus are very small, and are situated near the junction of the cerebral lobes with the optic ganglia, and each gives off its nerve directly into the antennæ. From the enlargement of each

* Since this paper was delivered to the Royal Society I have found that, in the embryo of *Necrophlœophagus* (*Geophilus*) *longicornis*, Leach, at the moment of bursting its shell, the brain is composed of *four* double ganglia, the centres of a corresponding number of segments, which are then becoming aggregated together to form the single moveable portion of the head in the perfect animal; so that the brain of the Myriapod, and probably also of all the higher Articulata, is, in reality, composed of at least four pairs of ganglia.—G. N., July 14, 1843.

† Observations on the Anatomy, Habits, and Economy of *Athalia centifoliœ*. 8vo, 1838, p. 10.

‡ *Op. cit.*

lobe at its junction with the descending crus, a thick trunk of nervous matter (*e*) is extended forwards and transversely across the front of the head, above the palate and mouth, and uniting with its fellow from the opposite side, forms in the middle line a small triangular ganglion (*f*). These nervous trunks are the analogues of the recurrent nerves in insects, from which the visceral nerves (*k*) take their origin. In these Myriapoda the recurrent nerves are more extensively developed than in the other classes, and they seem to decrease in importance as in size, in proportion as the other parts of the nervous system are developed. The small triangular ganglion formed by them above the palate, sends backwards in the middle line a short thick nerve, which terminates immediately before the brain in a more indistinct ganglion that gives off three branches. The middle one of these is much smaller than the lateral, and passes backwards beneath the brain along the pharynx and œsophagus in a small triangular space between the lobes, covered by the median vessel from the heart, that passes between it and the brain and gives vessels to that organ. This median nerve from the recurrent ganglion constitutes the trunk of the proper *vagus nerve* (*l*); while the others from the same ganglion, each of which is more than twice as large as the vagus, after giving off some minute filaments to the pharynx and œsophagus, descend to the sides of the pharynx and pass backward between it and the crura cerebri (*g*) on each side (*h*), to unite at a short distance behind the brain with a series of large visceral ganglia (*m*) collected together, and constituting the analogues of the *anterior lateral ganglia* of insects. This series of ganglia, as in insects, is connected to the brain by two small communicating nerves (*n*), extended backwards from the posterior surface of the lobes, near where they are joined to the optic ganglia. These lateral, visceral ganglia in Iulus, are of most extraordinary size, being nearly half as large as the brain itself. There are four on each side of the œsophagus, closely connected in one series, extended along the œsophagus as far as the middle of the first or pro-thoracic segment, giving off branches of nerves to the immense salivary glands, to the œsophagus itself, and to the surrounding structures. They exhibit the appearance of masses of gray nervous matter inclosed in a distinct theca. The last of the series extends a little further backwards than the aortic arches given off from the anterior chamber of the heart. They seem to be the anterior of an extensive series of visceral ganglia, distributed in great part to the salivary glands. They communicate with the vagus by means of a nerve that passes directly from the last of these ganglia, on each side, to a large ganglion formed on the vagus (*o*) at some distance from the brain. The vagus nerve, after passing beneath the brain, forms a minute ganglion (*i*) immediately behind it, which is also connected to the lateral ganglia by a very minute branch on either side. It then passes along the œsophagus and forms the second larger, rounded ganglion, first mentioned as connected to the last of the lateral ganglia. After this it continues its course backwards half way along the œsophagus, and then divides into two branches, which are given, as in insects, to the posterior part of this organ, and to the cardiac extremity of the stomach.

One of the most interesting circumstances connected with the development of the nervous system in Iulus, is the relative size of the brain as compared with that of these ganglia of the viscera. In these inferior Myriapoda, in which the power of locomotion is distributed equally to every segment of the body, the brain itself forms but a small proportion of the whole nervous system, and the faculties of sense are less perfect than in insects; while the nerves of organic life, and their ganglia, are nearly equal in volume, as in Iulus, to the whole brain, the organ of volition. The very reverse of this is the case in insects. In those in which the faculties of sense, more especially of vision and smell, and the power of voluntary motion are carried to their greatest extent, as in volant insects,—the gregarious Hymenoptera, Neuroptera, and Lepidoptera,—the volume of brain bears a much larger proportion to the rest of the nervous system, and the ganglia of organic life a smaller. This is more especially the case in the perfect insect, in which the volume of brain is not merely relatively, but actually increased in size during the changes from the larva to the perfect state, thus leading to the inference that the importance of the visceral nerves is gradually diminished in proportion as those of volition and active existence become augmented.

Notwithstanding this inferiority of organization in the nervous system of Iulus, the brain is inclosed in a proper covering, and is separated from the surrounding structures by a distinct membrane, but this is so delicate as to be detected only with some difficulty. It is completely inclosed in this structure, which also sends off prolongations that form a covering for the œsophagus with its vessels and nerves.

The *nervous cord* is extended from its commencement in the crura of the brain (*g*) and medulla oblongata, or first subœsophageal ganglion (*h*) to the antepenultimate segment of the body, and is almost uniform in size throughout its whole length. It is slightly larger at its anterior, and smaller at its posterior extremity, than in the middle part of its course. In *Iulus terrestris* it has ninety-six very minute ganglionic enlargements, situated entirely on the under surface of the cord, and so closely approximated together as not to be observable, except on very close inspection. Each of these enlargements gives off two pairs of nerves, one of which, on the under surface, is given to the legs, and the other, on the lateral and superior surface, to the sides of the body; so that the whole number of nervous trunks from the cord, including those from the medulla oblongata, is ninety-four pairs to the head and sides of the body, and ninety-two pairs to the legs, making in the whole one hundred and eighty-six pairs, or two hundred and seventy-two nervous trunks from the cord, exclusive of those which belong more immediately to the brain. In *Spirostreptus* (fig. 3.) the ganglia are even smaller and closer together than in Iulus, but the cord is larger in proportion to the size of the nerves, the distribution of which is almost precisely the same as in Iulus. Each enlargement of the cord (*a*) gives off at its upper and lateral surface a single nervous trunk (*b*), which passes outwards for some distance as a single nerve, but which in reality includes two distinct sets of nerves,

that separate as principal trunks at the inner side of the great longitudinal series of abdominal muscles. The anterior of these trunks (*e*) is the analogue of the respiratory nerves of insects, and passes across the upper layer of these muscles, on their visceral surface, giving off to them many minute branches. The first of these branches turns backwards and inwards, in the direction of the spiracles and principal tracheæ, on the under surface of the segment behind the legs, while the main trunk of the nerve, greatly reduced in size, passes upwards to the muscular appendages of the heart. The other set of nerves is divided into two main trunks, which pass between the layers of longitudinal muscles, the first of them (*f*) giving off branches to the muscles of the inferior and lateral parts of the body, to which it is almost entirely distributed; and the other (*g*), the larger of the two, passing round the sides of the body, is distributed to the dorsal muscles. Besides these regular branches each alternate pair of nerves gives off a branch from its posterior surface (*h*), near its origin from the cord. This branch is given to the muscles that connect the two segments. The second pair of trunks (*d*) from the ganglion, as in Iulus, is given directly to the legs, and send off only one small branch to the coxæ before entering them.

Structure of the cord.—The formation of the great abdominal cord in the Iulidæ, by the lateral approximation of two distinct portions, is indicated on its upper surface by a slight median sulcus, and on its under surface by a slight longitudinal division between the two approximated ganglia that form each of its enlargements. Each of these lateral divisions of the cord in Iulus, as formerly shown in the Scolopendra and other Articulata, is a compound structure, formed of two distinct longitudinal series or columns of fibres, which, notwithstanding the different explanation that has been given of their function, since I had the honour of first describing them to the Royal Society*, are quite distinct from each other, although closely approximated together. By the aid of means superior to those formerly employed in my investigations, I now find that the abdominal cord contains other structures besides those already described. In my former communication to the Royal Society, I indicated the existence of fibres that run transversely through the ganglia of the cord in the larva of the common butterfly†, and similar structures have since been shown by Dr. CARPENTER‡ in other Articulata, and applied to explain some of the reflex phenomena of the nervous system, in accordance with the theory promulgated by Dr. MARSHALL HALL. But besides these two sets of *longitudinal* fibres, and the series that passes *transversely through the ganglia*, there are other structures in the cord that have hitherto been entirely overlooked. These are fibres that run longitudinally, in part of their course, at the *sides* of the cord, and enter into the composition of all the nerves from the ganglia. These fibres I shall designate the *fibres of reinforcement of the cord.*

The *superior longitudinal* set of fibres of the cord (fig. 4. *e*), which I formerly

* Philosophical Transactions, 1834, Part II. p. 408. † *Op. cit.*, p. 412, Plate XVI. fig. 37.

‡ Inaugural Dissertation on the Physiological Inferences to be deduced from the Structure of the Nervous System in the Invertebrated Classes of Animals, by WILLIAM B. CARPENTER, M.D., 1839.

described as the *motor tract*, and to which the function of volition seems still to be accorded by VALENTIN*, CARPENTER†, and BALY‡, is extended in Iulus, as in other Articulata, as a separate fasciculus along the upper surface of the cord; but in these Myriapoda it is much narrower in proportion to the whole width of the cord than in insects. This fact is interesting in reference to its presumed function. On a cursory inspection it does not appear to give off any branches, but seems to pursue its course uninterruptedly along the whole length of the cord. It does not indeed give off filaments to the nerves from a ganglion immediately opposite to their origin, while passing over that ganglion, but immediately it has passed one ganglion it gives off the filaments that proceed to the nerves from the next ganglion. These filaments seem almost immediately to join with others that belong to the sides of the cord, and pass out with them into the nerve from the next ganglion along its anterior surface. This is almost precisely the manner in which the filaments from this aganglionic column in the Crustacea are united with those from the ganglionic, as formerly shown in my description of the nerves in that class, when the existence of the lateral fibres of the cord was unknown to me.

The *inferior longitudinal*, or *ganglionic* set of fibres (fig. 5. *a*) of the cord, affords many interesting considerations. It is placed, exactly as in insects, on the under surface, but like the upper series it is narrower than the whole cord, of which it forms a part. It is formed of a longitudinal series of fibres, like the upper tract, beneath which it is placed, and from which it is divided by some of the fibres that pass transversely through the cord, and which enter into the composition of the nerves from the ganglion on either side. It appears also to receive filaments from the upper series, and perhaps others are sent from it to the upper, thus decussating each other in the middle substance of the cord, where these two longitudinal series are in close apposition; since it is almost impossible, even in the large nervous cord of Scolopendra, to separate these two tracts from each other, although their distinctness is evinced in their relative size and longitudinal lines of separation. But there is one fact of great interest in regard to this ganglionic series of fibres. Almost the whole of the fibres of which it is composed are traceable, in the Iulidæ, directly through each enlargement of the cord, which they mainly assist to form. At the anterior part of each enlargement the diameter of each fibre, or fasciculus of fibres, appears to be slightly increased, and its structure becomes more softened and delicate. While passing through these ganglionic enlargements, occasioned chiefly by their own increased diameter, the fibres take a slightly curved direction outwards, and then inwards, but are reduced to their original size, and assume the longitudinal direction on again forming the aganglionic portion of this tract of the cord. This structure of the fibres is well seen in the *Iulidæ* and *Polydesmidæ* (fig. 7. *i*), as I shall hereafter

* De Functionibus Nervorum, Bern. 1839. (*Vide* BALY's MÜLLER.) † *Op. cit.*

‡ MÜLLER's Elements of Physiology, second edit. vol. i. 1840, p. 771.

again have occasion to refer to, more especially with reference to the true structure of ganglia. The fibres are traceable most distinctly in the Iulidæ.

These are the structures to which I formerly assigned the function of voluntary motion and sensation, and to which I am still inclined to believe they minister, since the fibres of which both are composed are traceable to the crura and brain. Whether these functions are restricted separately to the two structures, as I first imagined, the one to the upper and the other to the inferior series, or whether they are administered to conjointly by both, through an interchange of fibres, it is almost impossible to determine by any decisive experiment on these animals, although the structures themselves are distinct. But in the absence of experimental proof there are circumstances connected with the distribution of the nerves to the extremities which seem to indicate, that these low forms of Articulata are endowed with a power of sensation and feeling far beyond what has of late been adjudged to them by some physiologists. In some of the gigantic *Spirostrepti* and *Spiroboli* the legs are adapted for climbing up the trunks and branches of trees, by the under surface of the first and second basilar joints of the tarsi being developed into a soft cushion or pad, as in some insects; and to these parts of the limbs I have found the nervous fibres more extensively distributed than to any other; a fact most strictly analogous to that of the distribution of nerves in the tactile parts of the limbs of Vertebrata.

Those fibres of the cord which seem to be independent of the sets just described, and which do not appear to have any direct communication with the great seat of sensation and volition—the brain,—are of two kinds, which may justly be regarded as *involuntary* in their functions. The first of these are the *commissural fibres* (figs. 4. 5. 7. *g*) which pass through the ganglia; and the second are those which have hitherto been undescribed, and form the sides of the cord (*f*) in the interspace between the ganglia, or between certain nerves distributed from them—*the fibres of reinforcement of the cord.*

The fibres of reinforcement of the cord form the lateral portions of the whole nervous cord of the body, and enter into the composition of all the nerves. They constitute, as it were, circles of nervous communication between two nerves that originate from the cord at a greater or less distance; and form part of the cord in the interval between these nerves, and bear the same relation to the segments, individually, which the cord itself does to the whole body. They form a part of the nervous trunks which come off from its upper, or aganglionic tract, as well as of those which proceed from the ganglionic enlargements in the lower, and in each instance they bound the posterior side of one nerve and the anterior of another, to which they proceed along the sides of the cord, forming, in the interspace, a part of its structure. Each fibre may thus be traced from its peripheral distribution, in the structures of the external surface of the body, inwards, along the course of the nerves, on their posterior surface, to the cord, where its direction is altered from that of the nerve

transversely inwards, to that of the cord on which it is reflected, and passes longitudinally backward; thus forming a part of its external surface until it arrives at the root of the nerve to which it is to be distributed, and along which it again passes transversely outwards, bounding the anterior side of the nerve to its distribution on the lateral surface of the body. These fibres of reinforcement form a large proportion of the whole cord, and enter into the composition of the upper, anterior, and part of the inferior surface of the root of every nerve, in their course inwards to the cord; and of its posterior and inferior surface on their again proceeding outwards. In this manner these fibres of reinforcement connect all the nerves of the cord on one side of the body, as the corresponding fibres do those on the opposite side. They form, as it were, double, treble, or quadruple circles, one within the other. Thus the fibres that pass inwards along one nerve may proceed along the cord to pass outwards again on the front of a second, a third, or a fourth, thus linking the segments in one continued series of nervous communications, independent of the brain. But these communications exist only between nerves on the same side of the body, and not between those on the opposite. The *commissural* nerves connect the opposite sides of each individual segment, as those of *reinforcement* do the same sides of two separate segments.

Every nerve from a ganglionic enlargement of the cord is thus composed of *four sets* of fibres, an upper and an under one, which communicate with the cephalic ganglia; a transverse or *commissural*, that communicate only with corresponding nerves on the opposite side of the body; and a lateral set that communicate only with nerves from a ganglionic enlargement on the same side of the body, and form part of the cord in the interspace between the roots of the nerves. It is by the successive addition of these lateral portions of the cord that its size is maintained almost uniformly throughout its whole length in the elongated bodies of the Myriapoda. On examining the cord very closely, I have reason to believe that the upper and inferior sets of longitudinal fibres, the ganglionic and the aganglionic, are somewhat smaller at their posterior than at their anterior extremity, a circumstance readily understood in the fact that successive series of filaments are given off from them at each distribution of nerves from the ganglionic enlargements, while the relative size of the lateral portions of the cord appears to be greater in the posterior than in the anterior. On this account I have named these lateral fibres, *fibres of reinforcement of the cord.*

In regard to the identification of these fibres, it may be well further to state, that their separate existence is indicated chiefly at the postero-lateral margin of the ganglia, (fig. 7. *f*) where they are seen to form part of the nerves and cord without passing upwards to the brain. In other parts of their course they are not distinguishable by colour, and very rarely by any longitudinal line of separation from the fibres which form the inferior longitudinal series, or portion of the cord, to which they are approximated; but from which they are believed to be distinct from the fact, that they do not ascend with them to the brain. Their function must be regarded only as

reflex; entirely independent of sensation, but capable of being excited into action by external causes.

The existence of these lateral fibres in the cord may now fully explain the reflected movement of parts anterior or posterior to an irritated limb on the same side of the body, as the commissural ones do the movement of parts on the side opposite to that which is irritated. The presence of these fibres in the cord of insects I had long suspected, from the curved direction of the fibres that bound the ganglia, and from that of the origins of the nerves from the aganglionic tract, as figured in my former paper*; and although I had communicated this opinion to a friend several years ago, I have never until recently been able to satisfy myself of its correctness.

This uncertainty of the existence of any structure in the cord that seemed sufficient to explain the reflected movements on the same side of the body, independent of the brain and the nerves of volition and sensation, long obliged me to withhold my assent to the doctrines now received respecting these phenomena. Although the fibres that pass transversely through ganglia might explain the effect produced on one side of the body, by the irritation of a corresponding part on the other, there seemed no anatomical structure to account for the movements of distant parts, anterior or posterior to a given point, on the same side, if the doctrine long received, that each fibre is endowed with but one special function, were correct. Now, therefore, that we find an anatomical structure in the cord that seems to account for these phenomena, I ought, in justice, to state, that Dr. HALL, to whom is due the high credit of collecting, comparing and arranging in one system numerous facts connected with the reflected movements of animals, as observed by WHYTT, BLANE and others, and also by himself,—adopting the principle established by our distinguished physiologist, Sir CHARLES BELL, that every nervous fibre is continued unbroken from its origin to its termination, and is capable of ministering only to one special function,—conceived the necessity for the existence of special nerves for the reflected movements; and that, at the period when I was engaged with Dr. HALL in his experiments on this subject, in 1833, he requested me to examine the cord in the Hedgehog to ascertain the correctness of his opinions. This examination was not made, because at that period I differed from him in attributing the reflected movements to the agency of another part of the nervous system. Now that the views of Dr. HALL seem proved to be correct, I am desirous of adding this testimony of the acuteness and perception of one who has done much for physiological science.

In the *Polydesmidæ* (Plate XI. fig. 6.) the nervous system corresponds with that of Iulus in regard to the nerves given to the generative outlets, but the ganglia of the cord are larger and situated at much greater distances. Those of the first two pairs of legs have united with the first subœsophageal ganglion (*d*), and the whole form one elongated large nervous mass, similar to the short nervous cord of the Ostracion and some other fishes. This great elongated ganglion is situated anterior to the

* Philosophical Transactions, 1834, Plate XVII. fig. 40–42, *g*.

outlets of the female organs of generation, and consequently anterior to the third segment of the thorax. From its posterior extremity the cord is continued backwards, in the middle line, between the female organs, immediately behind which it gives off a pair of nerves to these organs, apparently from the structure of the cord itself, but in reality from an atrophied ganglion (*e*), which has almost entirely disappeared from this part of the cord, precisely as similar ganglia disappear in the changes of insects; thus showing the constant tendency of the gangliated portions of the nervous cord to become united.

The number of segments in *Polydesmus complanatus*, Leach (Plate XI. fig. 6.), is twenty-two, including the head and anal segment. The number of ganglia in the cord, separate and distinct from each other, is thirty-four, each of which supplies one pair of organs of locomotion. Besides these there are the united ganglia (*d*. 1, 2.) which supply the manducatory organs and the first and second pairs of legs. The nerves from the atrophied fourth ganglion (*e*) above alluded to are given to the two ovipositors of the female, the analogues of a pair of organs of locomotion; and the thirty-eighth (37, 38.) is itself a double ganglion that supplies nerves to the apodal antepenultimate, penultimate, and anal segments.

The brain (*b*) in this family affords some interesting considerations. The two lobes are very small, pear-shaped, and developed on their under surface into very long and slender crura, which join beneath the œsophagus with the great aggregation of ganglia. Each of these lobes is rounded on the external side; and the optic nerves and ganglia are entirely absent, there being externally no organ of vision. On the front of each lobe there is a small elongated ganglion for the antennal nerve, which passes directly into each of those organs (*a*). This is a remarkable condition of the brain in these Myriapodes, and a similar one has been described by Treviranus* in Geophilus, although in that genus, as I shall presently show, the optic nerves are not entirely absent, as in the Polydesmidæ. This fact is especially interesting in reference to the analogy that is believed to exist between these lobes of the brain and optic ganglia, and the corpora quadrigemina of Vertebrata, and seems to show that their office is more important than that of simple ganglia of any individual organ; and that the ganglia of the optic nerves themselves are those by which impressions are received from the retina and transmitted to the middle supra-œsophageal ganglia, the brain, the common sensorium of the whole nervous system.

The distribution of the ganglia and nerves of the cord deserve particular attention. On entering the fourth segment the cord is somewhat elongated and passes between the double outlets of the female organs, immediately behind which it gives off the nerves to those organs from the atrophied ganglion. These nerves are exceedingly large, and ramify extensively over the muscles and distal portions of those retractile structures. Behind this atrophied ganglion the cord itself gives off a pair of nerves, which are distributed to the sides of the segment; after which it almost immediately

* Vermischte Schriften Anatomischen und Physiologischen inhalts. Bremen, 1817.

forms the next ganglion (4.) which gives nerves to the third pair of legs, the posterior of the two pairs of organs of the segment, the female outlets being the analogues of the first pair. In the male the organs are situated further backwards behind the seventh pair of legs. Posterior to the fourth segment of the female, and the seventh in the male, the cord is extended backwards nearly in a uniform manner throughout the remaining segments, as far as the thirty-second ganglion, when it becomes less uniform. In this first part of its course it forms two ganglia in each segment, as we have seen in the double segments of Iulus. These ganglia are separated only by a short interspace of cord (fig. 10. *d d*), but there is more than twice the length of cord between the last ganglion of one segment (8.) and the first of that next beyond it (9.). In the interspaces between these ganglia the cord gives off a pair of nervous trunks (*c*), which are distributed to the muscles and sides of the segments; and each ganglion gives off a single pair of nerves to the organs of locomotion (*d*). The nerves from the anterior ganglion in each segment are always directed backwards into the first pair of legs, since the ganglion is situated a little anterior to the coxæ, and is more elongated in form than the second ganglion, the nerves from which enter the legs in a more transverse direction. But in proceeding backwards along the cord the distance between the ganglia is gradually lessened, until in the posterior segments the ganglia are found to follow each other very closely, and almost to unite. So again in regard to the nerves. Those which, in the anterior part of the cord, are given from it at equal distances between the ganglia, are found nearer and nearer to the ganglion next behind, until they at length cease to come from the cord, but are derived directly from the ganglia, each of which then gives off two pairs of nerves, instead of the single pair to the legs, as in the anterior segments. But although the ganglia are thus closely collected together, this is not the result of aggregation in this part of the body, but is consequent on the non-completion of changes which take place in the formation of new ganglionic centres and nerves in this part of the cord, during the successive periodic formation and addition of new segments to the body in these animals, as I have heretofore shown in the Iulidæ*. These formations always take place in all the Myriapoda between the penultimate and antepenultimate segments, and in that part of the cord the new ganglia are produced to those segments. This leads us to some important facts in reference to the means by which the nervous cord itself is developed by extension and elongation of its fibres during the growth of the whole body, and the development of the new segments; and it shows that an elongation takes place in the longitudinal fibres of the cord in the new segments, and that ganglia are developed in its structure while commissural and lateral fibres of reinforcement are in the course of formation. But the distribution of the nerves from these ganglia, and the structure of the ganglia themselves, seem to lead us to the facts. In *Polydesmus maculatus* (fig. 9.), Nob., each of the six posterior ganglia gives off two pairs of nerves. In no instance in these posterior seg-

* Philosophical Transactions, 1841, Part II.

ments of the body do the nerves come directly from intervening portions of cord, or from spaces between the ganglia. The anterior pair from each ganglion are always given to the sides of the segment, like the nerves from the intervening cords in the anterior segments; and the posterior, to the legs. In the last-formed of these ganglia (36.) the ganglion is very short, the nerves (*c*, *d*) being given off from it almost transversely; and the whole corresponds to the diminutive extent of the posterior of these newly-formed and incomplete segments. The ganglion (35.) immediately preceding this is larger, and is separated from the one next before it (34.) by a more constricted portion of cord; and it gives off its anterior pair of nerves (*c*) in a diagonal direction forwards. So again the next ganglion (34.) is still more complete, corresponding to the greater length and more perfect condition of the segment, and is separated from its fellow (33.) anterior to it in the same segment, by a short portion of cord. These two ganglia still give off their anterior pair of nerves, but there are no nerves given off from the cord. The form of the ganglia is now changing, the anterior one is becoming elongated, and its anterior pair of nerves are given off from it in a direction more diagonally forwards and outwards. The length of cord between this ganglion, and that in the segment immediately before it, is now greatly increased, but still no nerves are yet given off from this portion of cord; they remain in connexion with the ganglion on which they have been formed. The ganglion (32.), anterior to this elongated portion of cord, also gives off both pairs of nerves, but the first pair are now at the very front of the ganglion, and are directed still more forwards, and appear as if exerting much traction upon it, while the ganglion is narrowed and greatly elongated, and seems as if it were about to separate. This separation between the nerve and ganglion actually takes place in the next segment, in which the ganglion gives off but one pair of nerves, while the anterior pair comes from the cord, in close approximation to the ganglion. In this way the interspace between the ganglia is increased from behind forwards in each segment, and is greater in proportion to its distance from the terminal ganglion. The cord is elongated in the ganglia, by extension, or growth longitudinally; and those nerves, which are given to the sides of the segments, and to the respiratory structures, and which originally are formed on the ganglia, or in immediate connexion with them, are gradually separated from them, and are afterwards attached only to the interspaces of the cord, so that they are removed to a greater distance from the ganglia in proportion to the earlier development and more complete state of the segment to which they belong. This elongation of the cord commences in the posterior ganglion, at the front of which, apparently by separation of part of its own structure, the new ganglion of each last-formed rudimentary segment is always produced. Hence the ganglia must be regarded as performing a most important office in the nervous system, that of being centres of growth and nutrition to the cord and nerves. The *structure* of the ganglia confirms these conclusions, and shows that not only are these parts centres in which the reflected motions of the limbs are effected, but that they are even of more importance,

being those in which the structures themselves are nourished. The vessels distributed over the ganglia penetrate into their substance, and are more abundantly supplied to them than to any other parts of the nervous system, as will hereafter be seen in the Scolopendra.

The *structure* of the ganglia in *Polydesmus complanatus* is well seen after the cord has remained for some time in spirit. When examined in the recent state it is far less distinct, but the nuclei, which enter largely into the composition of the ganglia, are well observed on the under surface. In specimens which have remained in spirit the whole of the fibres of the cord are rendered apparent, although the ganglia themselves are more opake. In *P. maculatus* the aganglionic tract passes in a direct line over the ganglia (figs. 9, 10.), as in other Articulata, and gives off its branches as in Iulus, at some distance anterior to the ganglion. The fibres of the inferior or ganglionic tract (fig. 7. *i*), on arriving at a ganglion, are softened and somewhat enlarged in diameter, and take a slightly curved direction outwards, as far as the middle of the ganglion, and then are gradually reduced in size and again directed inwards, until they are about to leave it, when they again assume the longitudinal course and form the under surface of the cords. This curved direction of the fibres is owing in part to their own enlarged structure, and in part also to the presence of numerous gray nucleated cells, which assist to form the ganglion. Between these two series of longitudinal fibres are placed the commissural ones (*g*), which pass transversely through the ganglia for the posterior pair of nerves (*d*). The fibres of reinforcement which form the sides of the cord are distinctly seen at the sides of each ganglion beneath the transparent covering of the cord (*b*), bounding the sides of the ganglion in the interspace of two nerves (*f*), and also at the posterior surface of the nerve where they join the cord, having between themselves and the commissural fibres, and fibres of the cord, a slight interspace, which is occupied by nucleated cells. Those fibres which belong to the anterior pair of nerves, which have been seen to be afterwards removed from the ganglia, have communications both with the anterior and posterior nerves, thus combining in action the nerves which are distributed to the muscles (*c*) and sides of the segment with those which are given to the legs (*d*). This fact is interesting from the circumstance that the commissural fibres which enter into the composition of these anterior nerves are placed above the superior aganglionic tract of the cord, and this will in great measure account for the removal of these nerves from above the ganglion, with which they are thus shown to be in connexion during the growth and elongation of the cord itself. It is also further worthy of notice, that this is a condition in these nerves of *Polydesmus* precisely analogous to that which exists in the respiratory nerves in the larva state of insects, in which, as I formerly* showed, there are commissural fibres running transversely across the segments and lying loosely above the aganglionic tract of the cord. In regard to the enlargement of the fibres of the cord, it may be remarked, that the ganglia are always softer and far more

* Philosophical Transactions, 1836, Part II. p. 544.

readily miscible in water, and more easily destroyed than the fibre of the cord itself; and that they usually break off (fig. 8.) on injury at their junction with the longitudinal portion of the cords, thus further leading to the inference, that in these parts the nervous substance is less consolidated, and that the growth of the structure is effected at these places. This view of the gangliated portions of the cord in Articulata may perhaps be extended to those of the cord in Vertebrata, seeing that in both there is an accumulation of gray nucleated cells in each enlargement. May not the office of these cells be to supply means of growth for the cord itself, and also for the large nerves distributed from the cord in those regions?

The *Geophilidæ* (fig. 11.) present a condition of the nervous system similar to that of the *Polydesmidæ*, in the size and distinct form of the ganglia, but they approach also to that of the *Iulidæ* in the uniformity of distance of the ganglia from each other, and in their great multiplicity. Their number varies much in different species and subgenera. In some instances, in *Mecistocephalus*, Newport (*Geophili maxillares*, Gervais), there are not more than forty-six, but in *Geophilus subterraneus*, Leach, there are eighty-six, besides those of the brain; and in a new genus, *Gonibregmatus*, Newport*, there are even so many as one hundred and sixty. In the higher forms of Chilopoda, as in *Scolopendra*, there are only twenty-three; and in *Lithobius* and *Scutigera* fifteen, besides the brain and medulla.

In *Geophilus subterraneus* (fig. 11, 12.) the brain (*b*) exhibits a condition similar to that of Polydesmus, in the almost entire absence of optic nerves. But it differs in the fact that the optic ganglia (*c*) are slightly developed at its sides, and that these give off a very minute filament to the single ocellus, which exists on the under side of the head, behind the antenna. Treviranus† has described the brain in *Geophilus longicornis*, Leach, as entirely without organs of vision; but from the existence of an ocellus in that species also, on each side behind the antenna, he has probably overlooked its minute nerve. The brain itself is large, as compared with the size of the head, and the ganglia of the antennæ (*a*) have almost completely coalesced with it. The nerves of the antennæ are also exceedingly large, and, as in Polydesmus, seem to compensate for the imperfection of vision, by appreciating the condition and proximity of surrounding objects by the sense of touch. Each nerve appears to have a small gangliform enlargement of its structure in every joint, from which branches pass off directly to the muscles. This is a condition of the antennal nerve not before met with in the Myriapoda. The crura which pass down from the brain are long and slender, and the medulla (*d*) with which they are joined is considerably larger than any of the other ganglia, the first fifteen or twenty of which are much closer together than in the middle portion of the animal; thus further showing the constant tendency of those ganglia, and parts of the cord that have acquired their full dimensions, again to approximate and unite. The form of these anterior ganglia is slightly different from that of the posterior. They are rounded, and give off one pair of nerves at their front;

* Proceedings of Zoological Society, Dec. 1842.

† *Loc. cit.* tab. vii. fig. 5.

in the posterior region of the body they are elongated, and somewhat oval. TREVIRANUS has correctly described and delineated them as giving off each three pairs of nerves, but he has not identified these with the nerves of *Scolopendra*, or of insects. It has been seen in Iulus and Polydesmus that each moveable segment of the body is originally composed of two others that have become united, and that each of these contains a ganglion. In Polydesmus the ganglia of each segment are nearer together than those of two separate segments, and notwithstanding the manner in which the intervening cords are developed, there is a tendency in the ganglia to unite. In Geophilus each segment is also composed of two parts, but one of these is much smaller than the other, and is fast disappearing. Hence the ganglion in each of these segments may be regarded as formed of the elements of two ganglia. Three pairs of nerves are given off from this ganglion in close approximation, at its posterior lateral surface, in the posterior half of the cord, but these are separated from each other in the anterior, in a manner similar to what we have already seen in Polydesmus. The posterior pair of nerves from each ganglion (fig. 13.81. *d*) are supplied to the pair of feet. Immediately anterior to these, and coming as it were from the same origin, the proper muscular nerves passes outwards to the sides of the segment. These nerves, as is the case with the corresponding muscular nerves in the larvæ of insects, pass on the outside of the longitudinal layers of muscles, between them and the diagonal muscles, to the sides and upper part of the segments, and thus are enabled to give off branches in their course to both layers. The third or anterior pair of nerves (*c*) are analogous to the respiratory nerves of insects. They pass off from above the ganglion on the upper surface of the cord, and after crossing the longitudinal layer of muscles, on their inner side, to which they give filaments, are distributed to the spiracles and muscles connected with them. These nerves vary a little in their mode of passing off from the ganglia, owing to the changes which take place in the ganglia, as already seen in Polydesmus. They are composed of fibres derived, as in that genus, both from the ganglion and sides of the cord, and its superior tract, above which they are formed by the union of these with a series of commissural fibres. In the posterior part of the cord (81. 82.) these nerves pass off in the same trunk with, but immediately anterior to, the second or muscular pair, but in the middle of the cord they pass off more anteriorly (fig. 14. *c*), while in the anterior segments, in which all the ganglia are slightly enlarged and rounded (fig. 12.), they pass off directly from the front of the ganglion. This pair of nerves is of great interest in the anatomy of the nervous system, since these are the analogues of nerves which exist in the Crustacea and in Insects, and in the latter, as in Geophilus, they are always given to the organs of respiration. They have the same relations to the other nerves and layers of muscles in all, but in Geophilus they lie on the superior longitudinal tract of the cord, in actual contact with a ganglion, deriving part of their structure from the ganglion, from the fibres of reinforcement, and from the aganglionic tract; and they also contain commissural fibres, precisely as in the respiratory nerves of insects. They exist in all the families of Chilopoda, but with this difference, that

in *Scolopendra, Lithobius*, and *Scutigera*, they appear to come off behind the ganglion, from the superior tract of the cord, to which they have been closely joined in these more perfect forms of the nervous system. This difference of position is readily explained by the changes which have been seen to take place in Polydesmus, and which are also in operation in Geophilus. In the posterior part of the cord, which is the part last formed during the gradual and successive changes of these animals, there is but a short space between these nerves, which lie above the aganglionic tract of the cord, and the commissural fibres of the nerves from the ganglia. But in the course of the development of the segments of the body by elongation, a corresponding elongation of the nervous cord itself takes place in the substance of the ganglia, and these nerves become further and further removed from each other in that part which lies on the cord above the middle of the ganglion, while they still remain attached to the other nerves at its sides, and thus form a kind of triangle (fig. 13. 80. *c*) above the aganglionic tract, as it passes over the ganglion. This elongation of the cords in the ganglion goes on, as in Polydesmus, until in the middle portion of the body these nerves have become released from those at the sides of the ganglion, and pass off from its anterior part. In the anterior third of the body they are directed forwards, but are still kept in contact with the ganglion by means of the lateral fibres of reinforcement, and also by a delicate set of fibres derived from the ganglion itself (fig. 14. *c*). These facts seem further to show that the ganglia are the centres in which the growth and elongation of the cord always take place, and also that the nerves of the cord are usually first formed in connexion with ganglia, although they may be afterwards removed from them by further growth and changes.

The compound structure of the cord is distinctly seen in Geophilus. The superior aganglionic tract is more clearly seen along the whole length of the cord, even while passing over a ganglion, than in any other genus. It is scarcely more than one-half of the width of the whole cord. The lateral fibres are also distinct, and may be readily seen bounding the roots of the nerves.

The disposition of the terminal nerves of the cord is curious. Each ganglion gives its pedal nerves backwards to the legs in the next segment, so that the penultimate pair of legs are supplied from the ganglion of the antepenultimate segment, and the terminal styles, or anal appendages, are supplied by nerves from the preceding segment. By this arrangement it is proved that the anal styles are not supplied by the terminal portion of the cord, as is usually the case, since there are three ganglia, much smaller than these, posterior to them (figs. 13 and 14. 83. *e a*). The anterior of these *caudal ganglia* (*c*) supplies the anal valves and segments, and may be regarded as the *anal ganglion*. The next (*e*), which also gives nerves to the anus, is partly supplied to the rectum, and part to the outlets of the female organs, which in Chilopoda are always placed in the same relation to each other as in insects. The terminal ganglion (*a*) is situated in the middle line of the junction of the *receptaculi seminis*, between these and the rectum, and corresponds in situation to a ganglion on the

junction of the oviducts in Gryllus. It always gives nerves to the terminal portion of the oviducts, as the preceding ganglion does to the rectum.

The nervous cord attains its maximum development in the Myriapoda, in the *Scolopendridæ* and *Scutigeridæ*. Each ganglion now gives off four pairs of nerves, the first and third of which are distributed to the muscles, and the second to the feet, while the fourth pair, the analogue of the respiratory nerves, lies above the ganglion at its posterior margin, but derives from it, as in Geophilus, part of its structure. It is closely joined to the side of the superior tract of the cord, from which at first it seems to be derived, as I formerly* believed when describing this structure. Its distribution to the spiracles in Scolopendra was subsequently shown in the Plates of Mr. Swan†, and its analogy to the respiratory nerves of insects has since been pointed out by Professor Owen‡. The existence of commissural fibres passing through the ganglia in Scolopendra, one to each nerve, was also made known by Dr. Carpenter§, but the presence of the lateral fibres of the cord has not heretofore been ascertained. These lateral fibres exist in the Scolopendra, as already described in the other Myriapoda, but are less readily observed than in Polydesmus and Geophilus, in consequence of the more perfect structure and approximation of all the parts of the cord. The ganglia of the anterior segments have approached nearer to each other than in Geophilus, more especially the first five, which are separated only by a short portion of cord. In *Lithobius* this approach of the ganglia is carried still further, and in the Scutigeridæ, in which the first seven ganglia are very closely approximated, it has reached its maximum. In these latter instances also, the brain has acquired a greater development, the optic nerves and ganglia are enlarged, and the separate organs of vision are greatly multiplied. The caudal ganglia are united into a separate larger ganglion in Scolopendra, and in Lithobius (Plate XIII. figs. 23 and 24, 17. 18.) form an elongated caudal appendage to the last great ganglion of the cord.

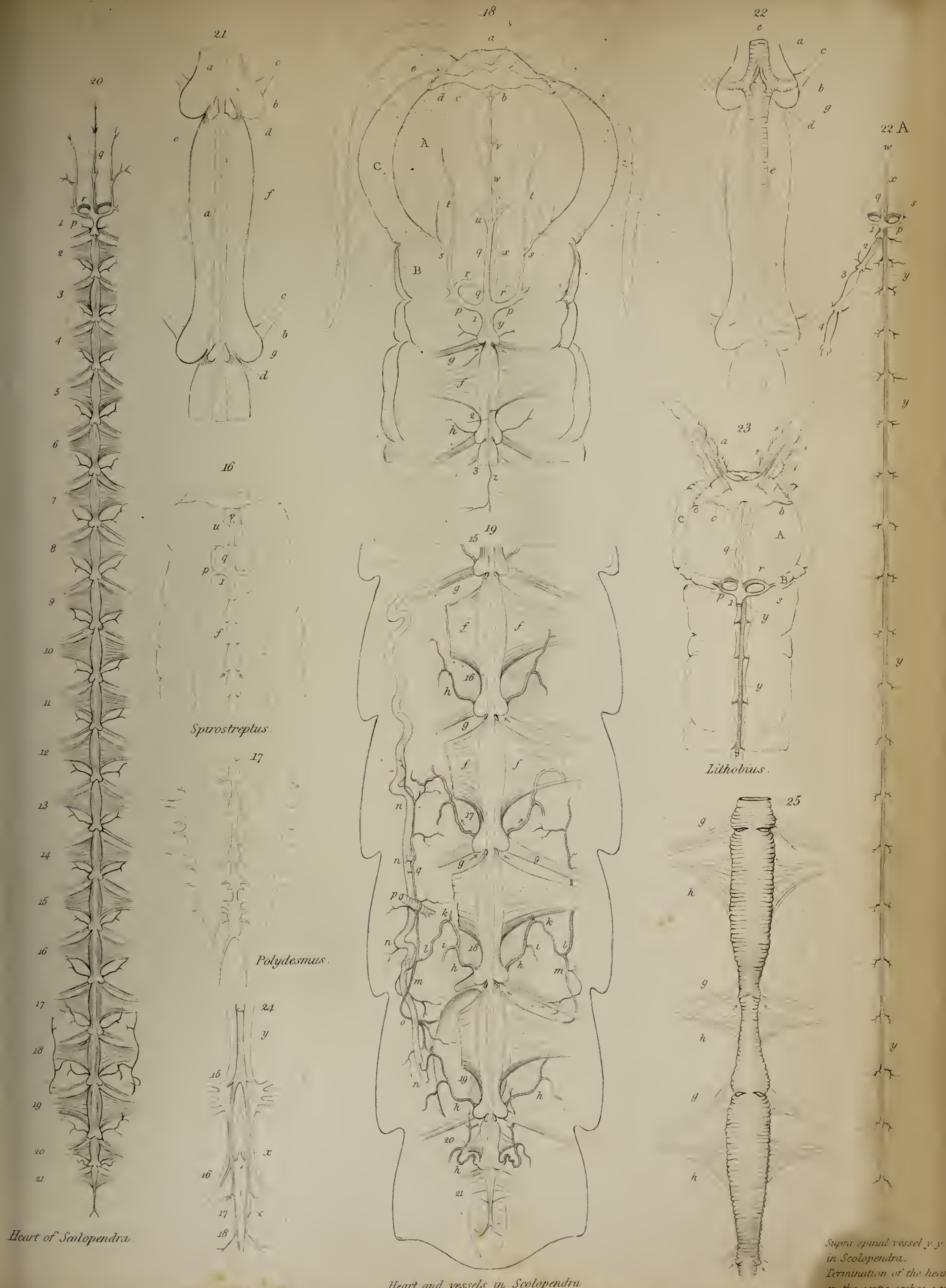
In the *Scorpionidæ* the nervous system exhibits two opposite conditions in the same animal; that of concentration of structures in the anterior part of the body and extension in the posterior, thus reminding us of the pseudo changes which are taking place in the anterior segments of the Iulus, while growth and elongation of others are taking place in the posterior. In the anterior part of the Scorpion the aggregation of segments has been carried to its greatest extent, the cephalothorax being formed of at least six segments that can be identified, and doubtless of still more; and not only have the ganglia of these segments been collected into one mass, but they have been joined by others from the segments of the abdomen, as in perfect insects and Crustacea. But instead of the nervous cord terminating in the abdomen, as in the most perfect of those classes, it is extended backwards and forms a series of ganglia in the tail, a condition which marks a close affinity to the macrourous Crustacea and

* Philosophical Transactions, 1834, Part II., p. 408.

† Comparative Anatomy of the Nervous System, 1835, Part I., Plate V. fig. 1.

‡ Hunterian Lectures, 1842.

§ Inaugural Thesis, 1839.



Heart of Scolopendra.

Spirostreptus.

Polydesmus.

Lithobius.

Termination of the Supra spinal artery

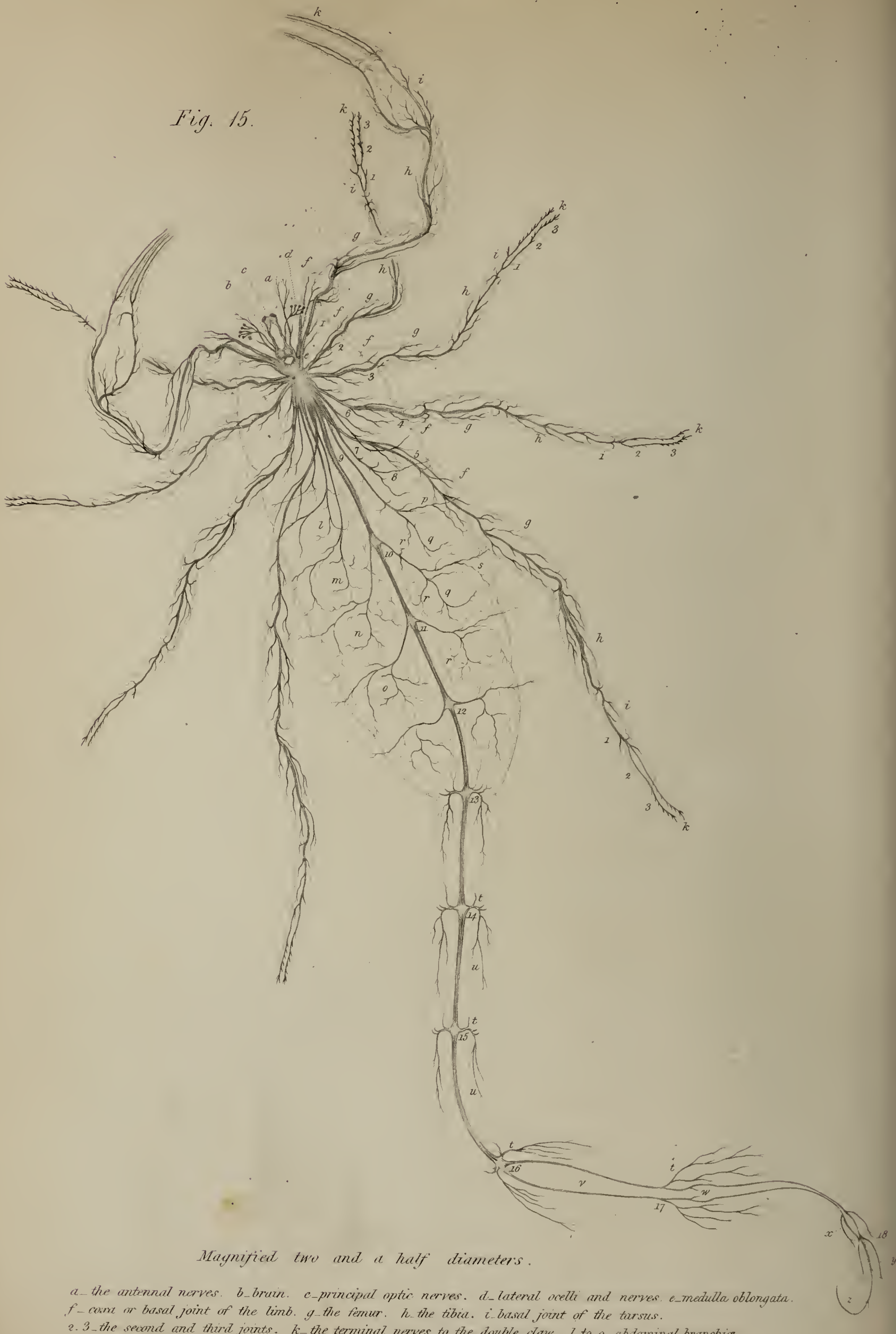
Heart and vessels in Scolopendra shewing the chambers & muscles f. valvular orifices g. Systemic arteries h. distributed on the Hepatic vessels l. n.

Chambers of heart in Scutigera.

Supra spinal vessel y. y. in Scolopendra. Termination of the heart in the aortic arches s. p

Nervous System of Arachnida.

The Scorpion. (Androctonus)



Magnified two and a half diameters.

a_the antennal nerves. b_brain. c_principal optic nerves. d_lateral ocelli and nerves. e_medulla oblongata. f_coxa or basal joint of the limb. g_the femur. h_the tibia. i_basal joint of the tarsus. 2. 3_the second and third joints. k_the terminal nerves to the double claw. l. to o_abdominal branchiæ. p. q. r. s_distribution of the nerves of the segments. t. u_nerves of the ganglia in the tail. v_terminal nerves. w_fifth joint. x_anal collar. y. z_termination of the cord in the extremity of the sting.

del.

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to the Myriapoda, more especially to the latter, in the number of ganglia that enter into its composition. Thus there are six ganglia which belong to the head and thorax, and four of the seven that belong to the segments of the abdomen, which enter into the composition of the great nervous mass in the cephalothorax, while three remain in the abdomen and four in the caudal region, making seventeen subœsophageal ganglia, a number equal to that of some of the Myriapoda, and more than is ever found in any hexapod insect.

The brain in the Scorpion (Plate XII. fig. 15. *b*) is exceedingly small. It is composed of two rounded, closely united ganglia, from the sides of which proceed directly upwards two small trunks, the optic nerves, which are given to the large median eyes (*c*) of the cephalothorax. At the base of these nerves, on the front of the brain, and arising from the same part, two other small trunks pass forwards and inwards to the middle line, around the muscles of the prehensile organs on the front of the head, and while passing outwards, on the upper surface, each is divided into separate branches for the lateral ocelli (*d*). These vary in number in different species. In *Buthus*, Leach, there are three on each side; in *Androctonus*, Koch, there are five, but in *Scorpius*, Ehrenberg, only two. Immediately beneath the nerves to the eyes a large nervous trunk passes forwards, from the front of the brain on each side, to the small prehensile organs (*a*), which, in the Scorpions, are modified antennæ. From the inner side of the front of each lobe of the brain, beneath these nerves to the antennæ, a small recurrent nerve passes forwards, and joins with its fellow on the opposite side to form a minute ganglion, from which a very small median trunk, the vagus*, passes backwards beneath the brain for a short distance along the alimentary canal, but I have not yet been able to detect lateral ganglia connected with this trunk, as in the Myriapodes. The brain is connected with the medulla oblongata (*e*) by very short and thick crura, so that it scarcely appears distinct from the great nervous mass in the cephalothorax. The *medulla oblongata* (*e*) forms the first portion of this great mass, from which it is distinguished by a slight construction, although closely approximated to it. It is spread out beneath the brain into a large concave ganglion, which gives off at its sides one very large pair of nerves, which are distributed to the great prehensile organs (1.), and which, from their origin, must be regarded as the analogues of the mandibles of insects, and of those of the forcipated foot jaws in the Chilopoda. These organs, as already shown by Savigny in other classes, are themselves the analogues of those of locomotion, as is well exemplified in the anatomy of these organs in the Scorpions. The nervous mass behind this first ganglion gives off four pairs of large nerves (2. 3. 4. 5.) to the organs of locomotion, and four pairs of smaller ones (6. 7. 8. 9.) to supply the abdominal segments, to which the trunks of these nerves pass backwards on each side of the cord, their ganglia being united with those of the thorax. The remaining ganglia of the abdomen (10. 11. 12.) are

* This vagus nerve is very small, and has been omitted on the drawing of the nervous system of the Scorpion, Plate XII., to avoid confusion.

situated at a great distance backwards in the cord, but not in the segments to which their nerves are distributed. These ganglia also have moved forward, and each is in a segment anterior to that which they supply with nerves. This shifting of the ganglia has also extended to those in the caudal region (13. 14. 15. 16.), each of which has moved forwards and is situated near the articulations of the joints of the tail, one in each of the first four basilar joints.

The distribution of the nerves to the legs affords an interesting illustration of the uniformity of plan in the distribution and use of similar structures in all animals. The great claw (*i*) of the Scorpion is formed by an arrest of development of the three tarsal joints (1. 2. 3.) that have coalesced into one large hand; but the finger-like digitations of this hand (*k*), which exist in the true organs of locomotion as minute claws, have become excessively developed, to form the two powerful fingers of the claw, as is proved by the manner in which the nerves are distributed. The great nerve of the limb in the other extremities is always divided into two branches immediately before or after it has entered the second joint of the tarsus (2.), and these are given separately along each side of the under surface of the tarsus to the two minute claws, exactly as the nerves are distributed to the digitations of the hands and feet of Vertebrata; and it is precisely in the same way that the nerves are distributed to these great claws in the Scorpion. But further evidence of the beautiful uniformity of design is afforded in the distribution of these nerves to the tarsi. As each division of the nerve is passing along the under surface of the last joint of the tarsus it gives off a distinct nerve to each of five spines (3.), which are arranged in a series on each side of the under surface of this joint of the foot, on which joint the animal usually rests. Can it be doubted that these nerves are to supply the rigid spines with sensation and a power of feeling, as this part of the foot is so constantly employed in touching and examining the objects over which it passes? The extremities of the two divisions of the nerves to the tarsus are extended into the minute claws (*k*) and terminate at the base of the nail, having first given off, on each side of the claw, a small branch to the muscles.

The nerves that pass backwards from the thorax into the abdomen continue distinct, and are given separately (6.7.8.9.) to the respective segments. Immediately each nerve enters its proper segment it divides into two branches (*p*, *q*); one of these (*p*) passes outwards in the anterior part of the segment, across the front of the branchia, and near the margin of the ventral plates this also is divided into two branches, one of which ascends to the dorsal surface of the segment, while the other passing backwards in front of the branchia (*s*) is given to the sides. The second branch (*q*) of the main trunk passes backwards in the segment behind the branchia, and gives off some ramifications to the muscles (*r*) on the ventral surface, and some are distributed over the branchia (*l*, *m*, *n*, *o*). This second branch of the great trunk is itself a separate nerve, the analogue of the respiratory nerve which exists so distinctly in all the Myriapoda, more especially in the *Scolopendra* and *Lithobius*. The aggregation of origi-

nally distinct parts, which has been carried to so great an extent in the ganglia of the cephalothorax of the Scorpion, has also taken place in the development of the ganglia and cord of each segment of the abdomen, in the union of all the primary trunks of nerves into a single pair in each segment; so that throughout the whole body each ganglion appears to give off only one set of nerves; and this condition exists even in the ganglia of the tail.

The cord in the tail has four distinct ganglia, one at the commencement of each of the first four joints. The terminal ganglion gives off two pairs of nerves. The first pair (t), are the proper nerves of the joint, and the second, the terminal nerves (v), are the continuations backwards of the two halves of the cord. One of these main trunks passes backwards on each side of the colon, and the two ascending, one on each side, and winding inwards, meet above it in the middle line of the dorsal surface, at the posterior part of the fourth caudal joint. On entering the fifth joint each trunk gives off a large branch to the muscles (17.), and then passes backwards, one on each side of the strong tendons of the flexor muscles of the dorsal surface. On entering the fifth segment these trunks again give off a pair of branches (w), but do not form ganglia. The two trunks, now reduced to small nerves, pass backwards in the middle line, side by side, and give off a few lateral branches to the muscles of the sixth joint, the *aculeated joint* of the tail, through which they pass parallel to each (y) other along the dorsal surface to the extremity of the poison duct (z) and point of the sting. At the termination of the fifth segment they send a branch on each side of the anus, which is thus inclosed between them (x) as in an elongated nervous collar, and immediately behind it (18.) they give off the branches to the base of the sting without forming a ganglion.

The nervous cord is narrowed and rounded in the abdomen, but in the tail it is thin and flattened, and spread out like a riband, and is larger in proportion to the size of the nerves, than in any other part of the body. Throughout its whole length the two halves of the cord are closely approximated, excepting immediately anterior and posterior to each ganglion, where the blood-vessels pass downwards from the supra-spinal artery to join the sub-spinal structures. The pair of nerves given off from each ganglion in the tail are divided into two sets of branches, and these are again subdivided. The anterior set (t) is the smallest, and is directed forwards and downwards to the muscles of the under surface of the joint. The posterior set (u) is divided into four trunks, which pass upwards and backwards, and are given, like the lateral branches from the terminal ganglion, to the great flexor muscles, which pass downwards on each side from their strong tendinous attachments in the preceding joint. The ganglia of the tail are oval, flat, and thin, like the cords, but those of the abdomen are thick and elongated, oval or spindle-shaped, but flattened on the upper surface. The two nerves, which are united into a single trunk at the side of each ganglion, are derived, one from its anterior, and the other from its posterior border. The anterior one (Pl. XV. fig. 38. a) passes backwards until it meets with the pos-

terior (*b*), which passes forwards to join with it, and these two approximated nerves, forming one trunk, have between their roots and the margin of the ganglion a very minute interspace, which is filled up with cellular tissue. Each of these approximated nerves contains distinct commissural fibres. Those of the anterior nerves are on the front of the ganglion, and are distinctly traced from side to side. Those of the posterior traverse the posterior part of the ganglion, and passing forwards on each side join with the lateral or *reflex* fibres of the cord, which ascend along the sides of the cord at the posterior part of the ganglion, or, as before described, if traced from the peripheral surface of the segment, pass inwards from the nerve to form part of the sides of the cord. The existence of the longitudinal tracts of the cord is also distinct. The fibres of the inferior series have a large proportion of gray nucleated cells interspersed between them in each ganglion, and these are more especially abundant and distinct at its sides. The caudal ganglia exhibit the different structures of the cord better than the abdominal ones, above which the superior aganglionic tract of the cord is less distinct, and is less easily observed in consequence of the greater opacity and thickness of the ganglia. I ought also to state that the structure of the cord and ganglia of the Scorpion, owing to their greater thickness and more compact and united condition, can only be satisfactorily seen in the very small specimens, or in the very early condition of the animal, and after being preserved for some time in strong spirit. This remark also applies to the Myriapoda and other Articulata.

Functions of the Brain and Nervous Cord.

Although I have now pointed out the existence of fibres in the nervous cord of Myriapoda and Arachnida, which lead us to the conclusion that the doctrine of the individuality, or special function, of each fibre is correct; that there are fibres in every nerve derived from two distinct portions of the cord, which from their direct communication with the brain, from one end of the body to the other, are believed to minister to volition and to sensation; and that other fibres also exist in the same nerves, that have no communication whatever with that organ;—and further, that some of these, which are extended transversely across the body, influence both sides of those individual segments to which they are distributed, and those only; while others combine in action two or more contiguous segments, but only by direct influence on one side of the body;—it yet remains to be shown by experiment, whether the assignment of certain functions to these parts of the nervous system, in these inferior animals, is correct;—whether the results of experiments on these worm-like beings agree in principle with the experiments already made by many physiologists on the vertebrated classes, and with those which the pathology of disease has afforded in Man himself;—whether, as leading to these important results, they coincide with the first experiment made on one of the Crustacea, conjointly by Dr. Marshall Hall and myself*, in the spring of 1834, and with others subsequently performed by

* Lectures, Lancet, Feb. 3, 1838, p. 650. Memoirs on the Nervous System, p. 67.

Valentin* on the same animal, and afterwards repeated by Dr. Baly and myself in 1840†; and lastly, whether the seat of sensation and volition is confined entirely to the supra-œsophageal ganglia, the brain, in these Articulata.

No experiments have yet been made on any of the Myriapoda with reference to these inquiries, save only one, imperfectly described by Dugès‡; hence it has become especially necessary that, with this object, our inquiries should be extended to these lower forms of life, so far removed from those on which experiments have already been made, and in which, from their low organization, the phenomena may be well studied.

With this object I have made experiments on one of the lowest of the Chilognatha, *Iulus terrestris*, and on one of the highest of the Chilopoda, *Lithobius forficatus*.

The questions that seemed necessary to be examined, were—

1st. Whether sensation and volition are confined to the supra-œsophageal ganglia, the brain, or whether they exist also in the first subœsophageal ganglion, or in the other ganglia of the cord?

2nd. Whether these functions are destroyed by partial destruction of the brain?

3rd. Whether there is any direct evidence of sensation in a portion of the cord that is insulated from the brain?

4. Whether the movements in these animals, when deprived of the brain, are identical with those of the Crustacea and Vertebrata?

Iulus terrestris.

Experiment 1.—The front of the head, antennæ, eyes, and brain were at once removed with a pair of scissors from an active adult specimen. While held between my fingers there were powerful contortions of the whole body of the animal, and when placed on a table it moved rapidly forwards, as in the usual mode of locomotion, and continued to do so for a few minutes, but the motions gradually became slower and slower, and at last were so feeble that onward progression was suspended, although the legs were still feebly moved, as in walking, for nearly half an hour, when their motions entirely ceased. There was no evidence whatever of sensation or volition, although the subœsophageal ganglion and cord were uninjured. During locomotion the body moved in a direct line, and always *forwards*. When it met with a slight obstacle it climbed over it, or when too high to pass over, the body stood directly opposed to it, with the mutilated portion of the head in contact with the obstacle, and the locomotive actions of the limbs gradually increased, apparently by the excitement of contact with a foreign body against the lacerated surface of the head. When the movements of the limbs ceased, the body was maintained in its natural position upon them for several hours, until fresh mechanical excitement was applied to it, when the locomotive actions were repeated.

* De Function. Nervorum, Bern. 1839. (*Vide* Baly's Müller.)

† Müller's Physiology by Dr. Baly, second edition, vol. i. 1840, p. 771.

‡ Traité de Physiologie Comparée, tom. i. p. 162.

Experiment 2.—The head was removed from the body in the *third* segment, the second of the trunk, and acts of locomotion were performed by the body precisely as in the last instance, and were always re-excited in the same manner. When turned on its back the body was instantly excited to violent contortions, until it had regained its proper position, and stood supported on the legs, which were extended, and slowly moved as in locomotion, after it had continued to walk for four minutes. When the anterior cut extremity of the cord was irritated with a needle, locomotion forwards was again induced. Pressure on the anterior segment excited it most readily. Motions of the legs were instantly excited by simple contact with any foreign body, and those on both sides, anterior and posterior, were moved, but insufficiently for locomotion. Violent contortions were always induced when the body was placed on its back, until its proper position was regained; but the motions of the legs were not excited by a current of air directed on them from a blowpipe, until after the lapse of a few seconds; but there was always a slight convulsive motion of the body after each *sudden* current. The legs were less excited during the first few hours after decapitation by pressure on the posterior than on the anterior segments.

Experiment 3.—The body was divided in the *seventh* segment while the animal was running briskly. It continued to move forwards for a few minutes, but the motions gradually became slower and slower, as in the preceding experiments. They were actively *re-excited* by a brisk shake of the table, but soon became quiet with slow but very gradual motions of the legs. Progression was always quickly reinduced by pressure on the anterior segments, and this was more active than when applied to the posterior. It was always reinduced when the cut extremity of the cord was irritated slightly with the point of a needle. At the expiration of an hour from the making of these experiments, the atmosphere continuing at about the same temperature, 56° Fahr., the excised heads of No. 2 and 3. were still living, and exhibited acts of volition, and that of the latter, with the segments and legs attached to it, made attempts to walk. Both of these moved the antennæ briskly, and touched objects that were near to them, as if to *feel* and appreciate.

Experiment 4.—The body was divided at the *fourteenth* segment, while running. The anterior part exhibited all the voluntary actions of the perfect animal, those of touching, avoiding, or seeking an object, and also of locomotion, but its movements were slow and were made with difficulty. This arose from want of proper counterpoise of the body, since when that was supplied by the proximity of the individual to the upright surface of any object, locomotion was well performed. The remaining portion of the body was then divided into two parts, both of which were instantly excited to movements of the legs when irritated, but without any power of locomotion, or ability of either part to support itself in its proper position. The motions of the legs were readily induced by a current of air, or when the segments were compressed, or the cut end of the cord touched with the point of a needle. At the expiration of *nine* hours the anterior division of the body with the head was dead, and not the

slightest voluntary or reflex action could be excited in it by any means. But the middle division of the same individual was readily excited to reflex actions of the legs, and contractions of the segments, by compression of the segments, by irritation of the cord with a needle, and by brisk currents of air from a blowpipe. These reflected actions were much stronger in the third or posterior division of the segments, and were all induced by similar means. After *twelve* hours they were feebler in the middle division of the segments, but were even more readily excited in the posterior. After *eighteen* hours they were scarcely perceptible in the middle division on the application of the needle, and not at all on compression; but they were still easily induced in the posterior, and continued to be so in the four or five posterior pair of legs, even at the expiration of *twenty-four* hours. The temperature during the interval was not higher than 64° Fahr.

Experiment 5.—The cord alone was divided in the *fourteenth* and also the *twentieth* segment, and the intervening portion was destroyed by breaking it down with a needle. The animal exhibited in the anterior part of its body all the evidences of perfect volition. It moved actively along, turning itself back on either side repeatedly, as if to examine the anterior wounded portion, which it felt again and again with its antennæ, and when attempting to escape, frequently turned back as if in pain and aware of some hindrance to its movements, but it seemed perfectly unconscious of the existence of the posterior part of its body, behind the first incision. In those segments in which the cord was destroyed, the legs were motionless, while those of the posterior division, behind the second incision, were in constant, but involuntary motion, the movements being similar to those of walking or running, uniformly continued, but without any consentaneous action with those of the anterior part, by which locomotion was performed, dragging the posterior divisions of the body after them. When the animal was held by the posterior segments, reflex actions were excited in the legs, and powerful contractions and gyrations of the whole animal were performed in those segments; but these movements appeared to be entirely the result of reflex actions of the muscles, since exactly similar ones took place in the whole body in decapitated specimens. At the expiration of *twelve* hours the most perfectly voluntary acts were performed by the head and anterior division of the body, such as locomotion forwards or to either side, avoidance of any obstacle, touching it with the antennæ, which were in rapid action as in an uninjured animal, and attempting to reach and to climb up an object presented to it, but not in immediate contact with it. But reflex movements alone existed in the posterior division, in which the legs were very slowly moved, even when the animal was not progressing. Brisk actions were now more easily excited in them than at first, either by contact with the segments, by irritation of one or two of the legs themselves, or by a sudden current of air. By these means, when the animal was lying still, actions were immediately excited in all the legs of the posterior part of the body anterior and posterior to those which were irritated, and these actions were induced in those of both sides of the body, but ap-

peared to commence on the opposite side, in the legs corresponding to those which were first irritated. In *eighteen* hours the anterior part of the body was quite dead, no motions whatever could be excited on it, either voluntary or reflex; but reflex actions were then readily excited in the posterior, and also slightly so by mechanical irritation, even at *twenty-four* hours.

Other experiments were now made on the brain itself without detaching the head of the animal from the body.

Experiment 6.—The brain was completely divided longitudinally in the centre by a fine pair of scissors. All power of recognising objects was immediately lost. The antennæ were perfectly motionless, and the animal at first moved directly forwards, as in the first and second experiments, dragging the antennæ along with it at the sides of the head. It passed on with the head and first segment elevated, and climbed over every slight obstacle, and when opposed did not turn to the right or to the left, but passed forwards with the legs moving rapidly as in the act of running. At the expiration of half an hour it had regained a little power in the left antenna, and then constantly moved in a circle to the left side. When either antenna was pinched a sudden convulsive movement was induced in the whole body, but the antennæ were not retracted when touched, as they always are by the uninjured animal. At the expiration of an hour, slight motion was regained in *both* antennæ, but the movements to the left side were still continued. The brain was now entirely destroyed with a needle. All power of volition, which seemed to have been partly restored, as well as the use of the antennæ, were instantly lost, and the movements of the legs and body were precisely similar to those already seen in the decapitated specimens. Pinching the antennæ did not occasion the slightest convulsion of the body, or reflected movements of the legs, but slight pressure on the segments immediately induced them, and also violent contortions of the whole body, especially when applied to the anterior segments. In this specimen the reflected movements were excited at the expiration of eighteen hours, but mostly so, at that time, at the posterior extremity of the body.

Experiment 7.—The brain was divided in the middle, and one lateral half with the antennal ganglion and optic nerve were removed. Some of the motions of the antenna of the uninjured side seemed to indicate the remains of volition. The animal coiled itself up and remained quiet as in health, but the posterior legs of the body were in constant motion. The power of recognizing objects appeared almost entirely destroyed. When the remaining lobe of the brain was irritated with the point of a needle, the body was again extended and excited to slow progression forwards, exactly as in the preceding experiments, but the power of moving was very feeble. At the expiration of two hours, the specimen having remained undisturbed in the interval, slow progressive movements *in a circle* were induced by pressure on the segments, and always in the direction of the *injured* side, the left in this specimen.

Experiment 8.—The lobe on the right side of the brain was removed, and the

results were precisely similar to those of experiments 6 and 7, and the movements were to the *right*, the side injured in this specimen.

Experiment 9.—The right eye and optic ganglion were both destroyed by puncturing with a fine needle. The antenna of that side of the head became completely motionless, and perception of objects was destroyed; but the animal still retained its voluntary powers, and was able to recognise objects on the left side, on which the antenna and eye were uninjured, and seemed to a great degree to retain their usual powers.

Experiment 10.—Both antennæ were cut off close to the head, leaving the brain uninjured. All the powers of the animal continued perfectly voluntary, and it sought or avoided objects as usual, but by means of the palpi and vision, with not the slightest indication of reflex movements. When the point of a needle was passed in at the antennæ, the animal gave indications of great pain by its movements, but these were not reflex. When placed on the table it again sought objects, and carefully avoided falling over, by changing its course when it arrived at the edge. The brain was then destroyed through the insertion of the antennæ, and the movements immediately became reflex, and soon ceased, except when they were artificially re-excited.

Experiment 11.—The eyes on both sides of the head were removed without injuring the brain or antennæ. Volition continued perfect, but the movements of the animal were slower, and all objects were very carefully explored with the antennæ; and it avoided nothing except when in direct contact with it, or when its presence had been ascertained by means of these organs. But immediately the needle was passed into the brain all the motions became reflex and precisely similar to those already detailed.

These experiments on Iulus sufficiently prove that the seat of sensation and volition is in the cerebral ganglia, and that when these are destroyed, or greatly injured, all consciousness ceases and the movements of the body are reflex, and not voluntary. But it seemed necessary to confirm these conclusions by similar experiments in a higher form of Myriapoda, in which, from the peculiar structure of the head, the cerebral ganglia could be removed from the body without removing the medulla oblongata, from which the nerves are given to the parts of the mouth; and further, that the experiments should be made on an animal in which the ganglia of the cord are large and quite distinct, and are removed from each other, and thus afford a better comparison with experiments made on the large Crustacea, in which the experiments on the brain cannot be so satisfactorily performed. The subject selected for this purpose was *Lithobius forficatus*.

Experiment 12.—The front of the head and the brain were removed at once by the scissors. All volition instantly ceased, and reflex movements were induced. The mandibles were in constant action as in manducation, and the body performed onward progressive movements, which gradually ceased, as in Iulus, but there were no attempts to escape. When placed on its back the body instantly regained its

position and remained with its legs widely extended. When quiet, progressive motions were instantly induced by touching the cut end of the cord, or by pressure on the anterior segment. When pressure was made over the posterior caudal ganglion, violent contortions of the whole body were induced, as in Iulus. The antennæ were completely paralyzed and dragged along the sides, and compression of them produced no retraction, or any movements of the body or legs. But contortions of the whole body were produced by compression of the mandibles, or of the posterior pairs of legs. When a brisk current of air was passed from a blowpipe along the sides of the body on the stigmata, no motions were induced in the legs until after a few seconds, and then they were regular but slight. A brisk knock on the table always re-excited the movements. At the expiration of half an hour the antennal subsegment was removed, leaving the medulla *in situ*. Progression was again induced, but more feebly than before. When pressure was applied on any of the segments the reflected movements were as violent as at first. The mandibles were now fixed, but contortions of the whole body were induced when these were pinched. These contortions were most violent when pressure was applied over the great subœsophageal ganglion, the medulla, but occurred also when the cut extremities of the crura were irritated with a needle.

Experiment 13.—The left antenna and side of the brain were removed together. The results were very similar to those in Iulus (experiments 6 and 7). The volition of the animal was greatly impaired, but when the remaining antenna was touched the animal gave full evidence of sensation by instantly retracting it, and when it was pinched the whole body was violently contorted. It was also frequently drawn between the closed mandibles, as if to cleanse it from anything adhering to it, as is the usual habit of this species. This was evidently the result of sensation, but not perhaps an act of volition, since in all other respects the movements most certainly were reflex. The movements were usually to the left, or injured side, but not invariably. At the expiration of half an hour the cord was divided between the fourth and fifth pairs of legs. Excessively violent movements were now induced, but when placed on its back the animal did not regain its natural position. Pressure on any of the segments produced motions of the jaws, as in the act of biting, but without any direction, consequently these were reflex. The cord was then divided between the seventh and eighth pairs of legs. The reflex movements of progression were now more imperfect, but continued longest in the *anterior* portion of the body. Powerful contortions were as readily excited in the posterior part as before, but these contortions were confined to the posterior half; since none were excited in the insulated portion of cord between the fifth and ninth pairs of legs, except on firm pressure of the ganglia. When the animal was placed on its back the motions to recover its position were feeble and ineffectual, and almost entirely ceased without the body recovering its natural position. But motions were instantly re-excited when pressure was made over any of the ganglia; and the limbs, both anterior and posterior to the ganglion pressed on, were thrown into violent actions on both sides of the body, exactly as in the original

experiment on the Lobster. Pressure on the cut extremity of the nervous cord, in the posterior half of the body, induced scarcely any movements. When the anterior portion of the body, with three or four pairs of legs attached, was separated from the posterior, there were acts of progression as in Iulus. But the most striking fact was, that when that portion of brain which had been removed from the head in connexion with the antennal ganglion and antenna was irritated, contractions were immediately excited in the joints of the antenna. How difficult to understand is the influence of that power which resides in this mysterious centre of all the animal movements!

Experiment 14.—The body was divided at a stroke between the second and third pairs of legs. Sensation was perfect in the head and two pairs of legs, with which there were voluntary attempts at locomotion. But volition and sensation were sooner lost than in Iulus, and this also was the case with the reflected movements, all which had ceased in less than three hours. In each of these experiments on Lithobius sensation and volition ceased in the anterior portion of the body in a few minutes, and sooner in proportion to the fewer legs connected with the head. Reflex actions continued to be manifested longest in the posterior portion of the body in Lithobius as well as in Iulus, and usually were most readily excited in those regions.

These experiments seem to lead to the conclusion that the seat of volition is solely in the supra-œsophageal ganglia or brain of these animals, since all direction of purpose, all avoidance of danger, all control over the movements of the body, either of speed or change of direction, are lost when these are much injured or removed. Volition ceases quickly when they are severely wounded, and is greatly diminished even when one only is slightly affected. This latter fact is indicated by the loss or diminution of purpose, and by the gyratory movements of the body. The experiments seem also to show that sensation may remain after the injury or removal of one lobe of the brain, as was proved by the retraction of the antenna when slightly touched on the uninjured side of the head, and by the cleansing and excited act of drawing it constantly through the mandibles; and further, that pain is felt when the cerebral lobes are injured, as when the needle was applied to them after the antennæ had been removed. They lead also to the conclusion, that all the phenomena which occur in the posterior parts of the body after the brain and cord have been separated are reflex or excited, and that these are most intense at the two extremities of the cord—the medulla oblongata, and the terminal ganglion; and further, that the reflex phenomena are always excited and do not occur spontaneously, and that their intensity is greater in proportion to the stimulus applied, and gradually diminishes until they entirely cease, or are re-excited, precisely as already shown by Dr. Hall in the Vertebrata.

The experiments both on the Iulus and Lithobius seem further to show, that the reflected movements cease first in the anterior part of the cord and its ganglia, and that they areretained longest in the posterior; that the movements are most powerful and continue longest when the cord is entire, the brain alone being separated from it; and that they entirely cease sooner in proportion to the greater number of

parts into which the cord is separated: further also, that the reflex phenomena are less readily excited in the anterior part of the cord, while it is still in connexion with the brain, and that they cease entirely soon after the cessation of volition in that organ; as in those experiments in which only a very short portion of cord was removed with it from the body.

Many of the phenomena are precisely similar to those which have heretofore been observed in the Crustacea. They agree in the circumstance that violent contractions of the segments and limbs, both anterior and posterior to a ganglion, are induced by irritation of that ganglion, both when connected with the brain and when insulated from it, thus proving these movements, in the latter instance, to be reflex; but there is as yet no direct *proof* that sensation does not also exist in these ganglia.

The general results of these experiments tend to confirm the belief that the fibres now pointed out in the composition of the cord and ganglia, and which cannot be traced to the brain, are those by which these movements are executed independently of that organ; and further also; that the reflex phenomena are most intense, most easily induced, and are of longest duration in those animals of low organization in which the volume of brain bears the smallest proportion to that of the whole nervous system, in which also volition and sensation are of small amount, and which have the body formed of the greatest number of similar uniform parts or segments*.

2. The Circulatory System.

The existence of a motion of the fluids in the Articulata has long been known to the microscopic observer. So long ago as the middle of the last century it was seen by Baker† in the limbs of some insects. But notwithstanding this, and the evidence of a distinct pulsatory action of the great dorsal vessel, as seen through the tegument in the larvæ of insects, the existence of a true circulation of the fluids in them and some of the neighbouring classes was doubted until the fact was demonstrated by Carus‡, and afterwards by Wagner§. Yet the means by which this circulation is

* While this paper has been passing through the press, I have repeated these experiments, on the functions of the brain and cord, with still more conclusive results on the Coleoptera, Orthoptera, Hymenoptera, Neuroptera, Diptera, and other hexapod insects. The cord was divided between the first and second pair of legs. The two posterior pairs of legs were immediately deprived of volition, and exhibited only reflex actions, while the anterior pair gave marked indications of being as completely under the influence of volition and sensation as in the uninjured animal. The cord was then divided between the first pair of legs and medulla oblongata, when these legs also were deprived of volition, and exhibited only reflex actions like the posterior.

Other experiments made on the brain itself, by removing that organ, or by simply separating it from the medulla oblongata and cord, without decapitating the insect, fully confirmed the experiments on the Myriapoda, in proving that the supra-œsophageal ganglia have the functions of a true brain, and are the sole seat of sensation and volition; and that although, when this organ is removed or is insulated from the cord, a regular, combined, and consentaneous series of muscular actions can be excited in the limbs, and locomotion induced, these acts are then entirely automatic, and are performed without the intervention of sensation or volition. August 29th, 1843.—G. N.

† On the Microscope, vol. i. p. 130. ‡ Nova Acta Nat. Cur. t. xv. p. 2. § Isis, 1832.

carried on, whether in vessels with distinct parietes, or in sinuses bounded by the other structures of the body, is still a matter of inquiry, and the existence of vessels in insects has recently been denied by no less an authority than LEON DUFOUR. LYONET* himself, in his admirable work on the Anatomy of the Cossus, states that he could discover no vessels connected with the great dorsal vessel, which he believed to be closed, and to contain a fluid. This also was the opinion of MARCEL DE SERRES, who regarded it as a structure for the secretion of fat. CUVIER also believed that this organ was entirely closed, and in consequence supposed that nutrition in insects is effected by simple imbibition. But so early as the year 1812, TREVIRANUS, in his account of the anatomy of the Arachnida, pointed out the existence of vessels connected with the sides of the dorsal vessel in the Scorpions and Spiders; but stated that he was unable to determine whether they are arterial or venous†. In a subsequent work in 1816‡, he has stated that no vessels exist in the Tracheary Arachnida, a remark which LATREILLE§ repeated in 1831; and in 1817|| TREVIRANUS stated, that none exist in the Myriapoda. But in 1825 STRAUS DURCKHEIM¶ discovered the existence of distinct chambers and valves, with lateral orifices in the dorsal vessel of insects, all which had been overlooked by TREVIRANUS in the Arachnida, but he was unable to discover any vessels connected with, or proceeding from, the dorsal vessel in insects. In the Myriapoda, he found the anterior portion of this structure in the Scolopendra divided into three branches, which are distributed to the head, and that the middle one of these gave off other branches, the course of which he was unable to trace. In 1828 CARUS published his discovery of a circulation in insects; and WAGNER in 1832, Mr. BOWERBANK in 1833**, and Mr. TYRREL†† in 1835, added some new facts. But our own countryman HUNTER, long before this period, seems to have been acquainted with the course of the circulatory fluids in insects, and with the existence of the lateral canals described by WAGNER, which he regarded as veins. Professor MÜLLER‡‡ also, in 1824 had traced a connexion between the dorsal vessel of insects and the ovaries, which he described as vascular, although that opinion was controverted by CARUS, TREVIRANUS, BURMEISTER and WAGNER. Some unpublished observations made by myself in 1829§§ on these structures, several years before I was acquainted with the observations of MÜLLER, led me also to regard them as vascular, and this opinion has since been strengthened by my recent discovery of

* Traité Anatomique de la Chenille qui range le bois du Saule. À la Haye, 1760, p. 427.

† Der Arachniden, 1812; and Vermischte Schriften Anatomischen und Physiologischen inhalts. Göttingen, 1816 (Die Spinne), p. 5.

‡ *Op. cit.* (Die Afterspinne), p. 32.

§ Cours d'Entomologie, &c. 8vo. Paris, 1831, p. 170–176.

|| *Op. cit.* Bremen 1817 (Die Scolopender), p. 31.

¶ Considérations Générales sur l'Anatomie comparée des Animaux Articulés. 4to. Paris, 1828.

** Entomological Magazine, vol. i. April 1833.

†† Proceedings of the Royal Society for January 15, 1835.

‡‡ Nova Acta Nat. xii. 2.

§§ Cyclopædia of Practical and Comparative Anatomy, Article "Insecta," vol. ii. No. 18. p. 979, Oct. 1839. See also Dr. ROGET's Bridgewater Treatise, vol. ii. p. 245, 1834.

vessels in Myriapoda and in insects. The bifurcation and distribution of the aortal portion of the dorsal vessel in insects was noticed in the first paper which I had the honour of submitting to the Royal Society*, and was also figured in a subsequent one†, in which I described a structure that had previously been seen by TREVIRANUS in the Scorpion, who believed it to be part of the nervous system, and by MÜLLER, who thought it was a ligament. This was also described by myself as a nervous structure, although subsequent examinations led me to suspect it was vascular, a suspicion which afterwards was found to be correct, by the discovery by Mr. LORD‡ that this structure in the Scolopendra has a direct communication with the anterior part of the dorsal vessel, by means of two lateral vascular arches, the continuations of the two lateral divisions of the dorsal vessel observed by STRAUS in the head of Scolopendra. These arches, descending one on each side of the œsophagus, and meeting in the middle line beneath it, form this single median vascular trunk, which is extended backwards above the abdominal nervous cord. The facts ascertained by Mr. LORD were immediately confirmed by my own observations, and the corresponding structure in the Scorpion was also shown to belong to the vascular system §, and to form in like manner a vascular collar around the anterior part of the alimentary canal. In addition to this vessel lying above the nervous cord, I then first described another system of vessels extended beneath it, the chief of which, placed immediately beneath the cord, communicates with the upper vessel, both anterior and posterior to each ganglion, by means of very short branches, while the inferior one is also connected with a system of vessels that ramify in the inferior part of the abdominal segments. I also noticed the existence of a large vascular trunk that is extended along the abdominal cord in perfect Lepidopterous insects, so that distinct vascular trunks were thus shown to exist in Myriapoda, Arachnida, and Insecta, similar to those already known in the Crustacea. Since that period I have succeeded in tracing other vessels in these classes, the distribution of which, and their connexion with the nervous system, I will now attempt to describe.

Structure.—The most rudimentary condition of the circulatory system in Myriapoda exists in the Iulidæ, the family most nearly connected by its mode of growth, as well as by the whole of its structure, with the Annelida. In the lowest genera of this family, the *Spirostrepti* and *Spiroboli*, BRANDT, the structure of the heart is exceedingly delicate, and its separate chambers are very numerous. Their number is almost equal to that of the segments of the body, being only two less than that of the whole number of segments, there being none in the head, or in the anal segment. The number of segments varies considerably in the different species, being in some of the *Spirostrepti* not more than forty-four, but in others so many as seventy-two, and in *Spirobolus* even seventy-five, so that in the latter there are sometimes as many as seventy-two or three distinct chambers to the heart. This structure is ex-

* Philosophical Transactions, 1832, Part II. p. 385.

† *Op. cit.* Part II. 1834. Plate XIV. fig. 12 *k*.

‡ Medical Gazette, March 3, 1838, p. 893.

§ *Op. cit.* March 17, 1838, p. 971.

tended along the middle line of the dorsal surface of the body beneath the muscles of the segments, and immediately above the alimentary canal, from which it is separated, in the Chilognatha, only by a very delicate peritoneal membrane. It is attached on the upper surface to the median line of the segments, by means of delicate suspensory muscles, one pair in each segment, as in the larvæ of insects. At its sides it has broad triangular muscles, which are collected into narrow fasciculi, and attached to the sides of the body, like the corresponding muscles, the *alæ cordis* already well known in insects. These muscles are formed of two sets of fibres attached to the sides and termination of each chamber. The *anterior set* is much the largest, and proceeds from the sides of the anterior half of each chamber, along which its fibres are extended, and intermingled with those of the external tunic of the organ. These fibres are gradually collected into fasciculi, on each side, which pass forwards, and are attached to the anterior lateral margin of the segment. These muscles assist to dilate the chamber, and to draw it forwards in the segment, while the ventricular, or contractile action is performed by the structure of the organ itself in the segment next behind it. The *second set* of muscles originates from the posterior lateral part of each chamber. This fasciculus of fibres is smaller than the first, and passes backwards and outwards, and is also attached to the margin of the segment, and seems to be the first to act in dilating the chamber. These structures exist in the whole of the Myriapoda, Arachnida, and Insects, and mainly effect the auricular, or dilating action of the heart, which, in these classes, is not a simple passive act, or the result solely of a relaxation of its own structure. The contractile, or ventricular action of the organ, is performed entirely by its own fibres, the structure and arrangement of which I shall describe in the Chilopoda.

The chambers of the heart are separated from each other by constrictions, or reduplications of the muscular tunics, as shown by Straus in insects, but these constrictions are only partial, and far less perfect than in insects, or in the Chilopoda, the most perfect Myriapods. Their rudimentary condition very much resembles that of the chambers of the heart in some of the lowest forms of the larvæ of Dipterous and Hymenopterous insects, in which the heart is scarcely more than an elongated vessel, very slightly constricted in each segment, and almost as simple as the dorsal vessel of some of the Annelida.

At each constriction of the heart in the Iulidæ (Pl. XIII. fig. 16. *f*), between two chambers, there are two transverse lateral orifices, as in insects, through which the blood enters the organ. Whether these orifices in the Iulidæ are the terminations of delicate veins, as I shall hereafter have occasion to show in the Arachnida, or whether they are simple apertures, that admit the blood from venous sinuses in the body, I am not certain. Most of my observations lead me to believe that they are the inlets of the venous trunks that bring back the blood to the heart. The vessels which I have already indicated in *Iulus** and *Spirostreptus*, as passing round the sides of the

* Philosophical Transactions, 1841, p. 103.

body in each segment, are given off near these orifices. The heart is inclosed in a delicate membrane, which excludes it from the surrounding structures. This covering ought certainly to be regarded as a *pericardium*, and not as an auricle, as supposed by Straus. The anterior chamber of the heart (*f*) is situated in the second segment (1.), and descends on the œsophagus at the junction of that part of the alimentary canal with the cardiac extremity of the stomach. It is there divided into three trunks of nearly equal size (*p*, *q*). Two of these pass, one on each side (*p*), around the œsophagus, and unite beneath it; thus forming a vascular collar around this part of the alimentary canal, as was first seen by Mr. Lord in the Scolopendra; while the other proceeds for a short distance and then gives off a second pair (*u*) of vessels, and afterwards a third (*v*), all which inclose the œsophagus, thus forming three vascular collars around this structure, very similar to those which encircle the alimentary canal in some of the Annelida.

The first of these lateral arches is of great importance in regard to the development of the vascular system. I propose therefore to call them the *aortic arches*. In *Spirostreptus* these are divided into two branches, the posterior of which surrounds the œsophagus to form the great median vessel of the abdomen, while the anterior passes forwards and downwards by the side of the œsophagus to the large mandibles, giving off at the same time a large branch that enters the head, and seems to be given to the inferior labium. The other two branches which surround the œsophagus give vessels to the maxillæ, and the middle trunk is carried forwards to the brain, beneath which it passes and terminates in the antennæ.

In all the Iulidæ the heart gives off in each moveable segment of the body two pairs of arterial branches, which have not hitherto been demonstrated in Myriapoda. These vessels, which I regard as the *systemic arteries*, I shall describe more particularly in Scolopendra (figs. 18 and 19. *h*). They proceed from the under surface of the posterior part of each chamber, and passing outwards in the course of the lateral muscles, as noticed in a former paper, distribute themselves to the sides of the body, to the viscera and to the organs of generation, thus indicating the existence of a complete system of arterial vessels, even in these low forms of the Myriapoda.

In this general structure of the circulatory organs in these vermiform Articulata, we perceive a shadowing out of the great circulatory organs of the higher animals. The ventricular heart, with its aortic arches and great descending aorta, is rudely sketched in this many-chambered great dorsal vessel or heart of the Myriapod, with its lateral arches uniting below the œsophagus to form the great channel for the blood to the organs of locomotion and sides of the body, a structure of which the type of formation is continued uninterruptedly, but gradually increasing in complicacy and importance as we ascend through this and the other classes of the Articulata to the lower forms of vertebrated animals.

In the observations already detailed on the nervous system of these animals, I have shown that each moveable segment of the body is double, and is formed originally of

two segments, which are anchylosed together from a very early period of growth; and that as the segments in the anterior part of the body become more and more nearly approximated, the gangliated portions of the nervous cord in those segments also become more closely united. Now what occurs in this respect in the nervous system takes place also in the vascular. Each double segment of the body in the Iulidæ contains, at an early period of growth, two distinct chambers of the heart, each giving off its pair of arterial vessels, and furnished also with its two pairs of lateral muscles. I have found these chambers distinct, and still separated in *Iulus terrestris,* so late in life as that which I shall hereafter have occasion to describe as the *ninth period of development,* when the individual possesses forty-four moveable segments. After that period the two chambers in each double segment unite and form but one chamber, while the reduplication of the muscular tunics, which form the boundaries of each double chamber, and in which are situated the auricular openings, becomes more complete. Each chamber of the heart, in the adult Iulidæ, has therefore two pairs of systemic arteries, and four pairs of lateral muscles. The union of the two chambers seems to be occasioned by the growth and changes induced in the external coverings of the body, at the period when the animal undergoes its semi-metamorphosis, or change of tegument.

The abdominal portion of the vascular system is less perfectly developed in the Chilognatha than the dorsal. The great ventral vessel, formed by the union of the aortic arches, is a wide dilated structure, that covers the upper surface of the nervous cord, and also the roots of the nerves to some distance from the sides of the cord (Pl. XI. fig. 3. *c*). Certain processes are extended along the nerves to a short distance, and then appear to separate, and to form for them a vascular sheath (*i*); but this, in reality, is only on their upper surface, since I have distinctly observed vessels passing off from these structures, which I have traced to a great distance along the trunks of the nerves, as will presently be shown in the Chilopoda. I have seen these vessels very distinctly in the *Spirostrepti.* The upper surface of the cord in these families is thus covered by a vascular structure, at least three times as broad as the cord itself and its ganglions. I have reason to think that this structure is in reality formed by two vessels, one on each side of the cord, but connected transversely by a membrane that covers the cord; and that, consequently, in these families the blood is sent backwards in a double stream, from the sides of which vessels pass off to the sides of the body in the form of a vast number of minute trunks, and not in two or three principal trunks, as we shall find in the Chilopoda. This condition of the abdominal vessels, closely resembling that of the Annelida, is indicatory of the principle on which all large vascular trunks are originally developed, by the formation, first of numerous minute branches, which anastomose, and are aggregated together in pairs, to form larger vessels. It is precisely similar in principle to the approximation of the ganglia of the cord to form enlarged portions of that structure, and to the lateral approximation of small branches of nerves in the formation of the principal nervous trunks of the body.

In the next family, the *Polydesmidæ* (fig. 17), the circulatory system closely resembles that of the Iulidæ. Thus there are the same divisions of the heart into chambers, which distribute systemic arteries, and the aortic arches are given off a little behind the head. But the development of most of the structures is more complete. There are fewer segments to the body, and chambers to the heart, and the latter are more muscular and distinct. The spinal vessel now forms a single large canal above the nervous cord, giving off fewer branches, but it still exhibits the remains of its original formation from aggregations of nucleated cells, which are distinct in its texture, but less so than in the corresponding structure in Iulus.

In the *Glomeridæ* the development is still more complete, and approaches in its general condition to that of the Crustacea.

In the *Geophilidæ*, the lowest of the Chilopoda, which still retain the general vermiform type of the Chilognatha, the segments of the body and the chambers of the heart are more numerous even than in the Iulidæ. But the whole organization of this family is greatly in advance of the Iulus. The heart presents a greater number of segments than in any other Myriapodes. In some species, as in *Mecistocephalus maxillaris*, Gervais*, there are only forty-six chambers, but in others, as in *Gonibregmatus*, Newport, there are more than three times that number, or at least one hundred and sixty. Yet notwithstanding this multitude of parts and segments, the whole organ and its vessels are further developed than in the Chilopoda. The chambers are divided by more distinct valves, and give off each but one pair of vessels. The aortic arches are a single pair, as in Scolopendra, and the supra-spinal artery is not so large as the nervous cords, but is a distinct vessel that gives off a few lateral branches, as we shall find in the next family.

In the *Scolopendridæ* there is a still more perfect development of the whole of these structures. The heart (figs. 18, 19, 20, 21, 22) is inclosed in a distinct membranous covering, which may be regarded as a true pericardium. It is also separated from the great mass of fatty omentum by which it is surrounded, and from the organs of generation, and the alimentary canal, which are situated beneath it, by a distinct, thick peritoneum, which entirely invests the alimentary canal, and in which a great number of circulatory vessels ramify and anastomose. The pericardium that incloses the heart is a loose, delicate membrane, between which and the sides of each chamber there is a slight interspace. It was regarded by Straus Durckheim as an auricle. It is attached to each chamber along the median line, both on the upper and under surface of the organ. At its sides it is reflected downwards and outwards, and has lateral prolongations that pass between the *ala cordis*, and seem to inclose vessels that return the blood to the heart. The number of chambers (1 to 21) is reduced in the heart of the *Scolopendra* to twenty-one, the anterior (1.) and posterior (21.) of which are the shortest and smallest. This number is uniform throughout the whole of the species, and the structure and distribution of the parts in all are very similar. In *Scolopendra alternans*, Leach, and *S. Hardwickei*, Nob., there are two short and

* This authority refers only to the specific name.

small chambers of the heart in the last dorsal, or preanal segment of the body (20, 21), but one only in each of the other segments. The posterior of these is of a pear-shaped form, and has four minute vessels at its extremity. The two middle ones are given to the posterior pair of legs, and the two outer pass backwards and upwards to the sides of the segment. The second chamber is short, and scarcely longer than broad. The other chambers are equal in length to that of their respective segments. The two posterior chambers, perfectly distinct from each other, but located in the same segment, are analogous to the two chambers which exist in each segment in the earlier periods of development, as we have already seen in the Iulidæ. The *general form* of each chamber of the heart (figs. 20. 21.) is very peculiar. It is dilated, and somewhat lobular and rounded at its posterior extremity (*b*), but is narrowed towards its middle portion, and again enlarged at its anterior (*f*), but is very narrow and constricted at its junction with the next chamber (*e*). This constriction in the young animal, in which I have most carefully examined these structures, is only in the external tunic of the organ, and is not extended to the interior. The *auricular orifices* (*d*) through which the blood enters, are situated at the point of junction of this part with the next chamber. They are two somewhat elongated oval apertures (fig. 21. *d*), in the external muscular coat of the organ, placed a little diagonally on each side of the median line, on its dorsal surface, and are divided only by a thin muscular partition. They are bounded externally by a series of curved fibres (*e*), the continuations of those which connect the posterior of one chamber to the anterior of the one next behind it. These orifices, when examined in specimens that have remained long in spirits, often appear bag-shaped and dilated, and the fibres that bound their external margin are then very distinct. They seem very much to resemble the apertures in the heart of Crustacea, and are, I believe, in their natural state continuous with the parietes of some exceedingly delicate venous trunks, that convey the blood to the heart. At the posterior part of each chamber, in the median line, on the dorsal surface, and extended backwards to the commencement of these orifices, there are a pair of suspensory muscles that pass diagonally upwards and backwards to their attachment in the next segment. These muscles still exist in the larvæ of insects, and appear to have considerable influence on the auricular action of the chambers, and the admission of the blood. At a corresponding part of each chamber, on its under and lateral surface, there are two large arterial trunks (*b*, *c*), which have already been mentioned in the Iulidæ as the *systemic arteries.* The distribution of these, which supply most of the blood to the viscera and sides of the body, I shall presently describe. The *alæ cordis* (figs. 18, 19. *f*) resemble those of *Iulus.*

The *minute anatomy of the heart* (fig. 22.) is exceedingly interesting. This organ is composed of two distinct contractile tunics, an external (*a*) and an internal one (*e*), each covered by its proper serous membrane. The *external tunic* is covered by the membrane that forms the inner layer of the pericardium. It is a very thick, muscular

structure, the fibres of which are loosely interwoven with each other. It completely incloses the second, or inner tunic, the proper ventricular structure, from which it may be separated without difficulty; and it also forms the external covering of the systemic arteries (*c*) at their origin, and may be traced along them to some distance from each chamber. The action of its fibres seems to be chiefly in the longitudinal direction, and thus to assist mainly in shortening the vessel. The *inner tunic* is formed of two sets of muscular fibres. The inner one of these, covered by a delicate membrane, lining the ventricle, consists of longitudinal fibres, which are most perfectly developed on its upper and under surfaces, and which are extended throughout its entire length, from the posterior segment to the head. The other set (*e*), which is external to this, is formed of numerous short, broad, transverse muscular bands, very much resembling in appearance the cartilaginous rings of the trachea in vertebrated animals. These transverse muscular bands are thicker and stronger than the longitudinal fibres, and form the sides of this tunic. They do not completely encircle the longitudinal ones, but pass only half-way round, on each side, having a space between those of the two sides, both on the upper and under surface. This space is occupied by the principal longitudinal fibres, to the sides of which the extremities of these transverse bands are approximated. They are not, however, all arranged in one parallel longitudinal series, but are placed alternately nearer to, or more distant from the median line. This arrangement of the transverse fibres may perhaps be of great importance in the action of the vessel, since the inequality and the necessarily varied direction of the forces of the successive contractions of these fibres must occasion a spiral or peristaltic motion of the whole organ, which may be necessary to propel the blood onwards. Physiologically considered, it may be of still more importance than is at first apparent, with reference to the structure of arterial vessels in the Vertebrata, and their function of conveying the blood; since not only does this arrangement exist in the heart of the Scolopendra, but also in the systemic arteries, given off from it in each chamber; and consequently, by the analogies of comparative anatomy, we may reasonably expect to find a similar arrangement, mode of action, and function of fibres in the arteries of all animals. The passages into the systemic arteries in the Scolopendra are free circular openings (*d*), bounded by these transverse fibres, the existence of which I have traced in the inner tunic of the arteries to a considerable distance from their origin. These openings are in the infero-lateral surface of the enlarged posterior part of each chamber of the great auriculo-ventricular cavity, into which the blood is poured, through the auricular orifices, on the dorsal surface. The auricular orifices pass close together through the internal tunic on its dorsal surface, a little posterior to the outlets of the systemic arteries on the under surface. From their postero-lateral margin a series of oblique fibres passes diagonally forwards, in the interior of the chamber, until meeting in the middle line they form a double valve, with its apex directed forwards, very similar in appearance to the tricuspid valve in the heart of Mammalia. This valve is extended forwards from the

upper surface of each chamber a little beyond the outlets of the systemic arteries, and prevents the return of the blood from the anterior of the chamber. I am not certain whether these valves are extended around the whole of the interior of the chamber, but believe that they exist chiefly at its upper and lateral surfaces, and are almost absent on the under.

The *systemic arteries* (figs. 18 and 19. *h*) given off from each chamber of the heart supply nearly the whole of the blood to the viscera and sides of each segment. They are each divided into two branches (*i*) at a short distance from their origin, and pass diagonally forwards in the segments, giving off numerous ramifications in their course. One of the main branches always passes backwards and outwards, and the other forwards and downwards among the viscera. The latter of these gives branches to the alimentary canal and to the ovaries, which are situated between it and the dorsal vessel, or heart. The posterior pair of these arteries, which belong to the second chamber (20), in the last segment of the body are of small dimensions, and seem to be given chiefly to the rectum and the terminations of the organs of generation. Their place is in a great measure supplied by the arteries of the third and fourth chambers, the largest and most extensively distributed of the whole series. These arteries I have examined more minutely than any of the others. Those which belong to the fourth chamber (18. *h*), in the nineteenth segment, pass almost directly outwards to the hepatic vessels (*n*) and divide immediately into two great trunks (*i*, *k*). One of these passes (*m*) backwards and downwards to the anterior of the twentieth segment, first giving off a secondary branch that distributes some minute ramifications to the coats of the hepatic vessels in its course; and then, turning inwards, it gives some branches to the investing peritoneal coat of the tracheal vessels in the twentieth segment; and then passes downwards (*o*) into the segment and divides into three branches, which are given in part to the colon and in part to the pyloric extremity of the stomach. The other branch (*l*), the principal division of this great artery, passes forwards in the course of, and very close to the hepatic vessel. Soon after it has separated from the posterior branch it gives off some small vessels that go to the great hepatic vessel and ramify in its texture; and others that pass downwards to the interior of the segment. It then accompanies the hepatic vessel (*n*) as far as the middle of the segment, where it meets with a large tracheal vessel (*p*) that is passing inwards to be distributed to the organs of reproduction. At that point it gives off another branch, which also passes downwards in the segment, and is given to the muscles and fatty structures. The main branch then winds round the trachea that passes between it and the hepatic vessel, and gives off some small ramifications that pass inwards with the trachea to their distribution. The main trunk of the artery (*q*) then pursues its course along the hepatic vessel as far as the seventeenth segment, where it forms some anastomoses with the systemic arteries of the fifth chamber. Throughout the whole of its course along the hepatic vessels, to which this branch of the artery is chiefly distributed, it gives off numerous small vessels that ramify in its coats, and other

larger ones that pass upwards to the dorsal surface of the body. This is the general distribution of the systemic arteries, their anterior branches (*k*) are given chiefly to the viscera, and their posterior (*i*) to the sides of the segments and dorsal surface.

The vascular collar (fig. 18. *p*, *q*, *r*) around the œsophagus is formed by the anterior pair of systemic arteries. These pass off from the front of the small anterior chamber of the heart (1.) at its termination in the basilar segment of the head (B), where this organ becomes divided into three trunks, as I have already shown in the Chilognatha, and have distinguished them from the other systemic arteries, as the *aortic arches*, from the great analogy which they bear to the connexions between the heart and its aorta in many of the inferior Vertebrata. They are found in all the Myriapoda in the same segment, not only in the Scolopendra, but also, as we have already seen, in the *Iulidæ* and *Polydesmidæ*, and in the higher genera of the Chilopoda *Lithobius* and *Scutigera*. In Scolopendra they pass a little forwards and outwards before they bend downwards to surround the œsophagus at its junction with the cardiac extremity of the stomach, and unite beneath it to form the great *supra-spinal artery*. While passing round the œsophagus each of these arteries gives off on its front a large branch (*s*), which, as shown by Mr. LORD, is supplied to the muscles of the great mandibles, or foot-jaws (C). This branch, however, like the other systemic arteries, is divided into two (*s*, *t*), one of which is given to the muscles of the foot-jaws, while the other passes into the first, or cephalic segment (A), and is distributed to the muscles of the pharynx and œsophagus, and anterior parts of the head. In *S. alternans*, LEACH, there are two branches from each arch, the posterior of which is supplied to the salivary glands. In all the species there are minute branches given off from the great branch of the arch to the upper and under surface of the œsophagus and cardiac portion of the alimentary canal. The small median trunk (*q*), given off from the heart on the œsophagus with the lateral arches, passes forwards along the œsophagus to the cephalic segment, in which it gives off two pairs of minute *secondary arches* (*u*, *v*), and then, becoming very much smaller, the main trunk is divided behind the brain (*b*) into some minute ramifications, which are given to that organ, to the eyes (*d*), and to the antennæ (*a*). The *secondary* arches give off a pair of branches to the maxillæ and internal parts of the mouth, and then unite beneath the œsophagus to form a small trunk (*w*) that passes backwards to the junction of the great aortic arches with the supra-spinal artery. This junction of the arches beneath the œsophagus takes place immediately above the second subœsophageal ganglion, where the supra-spinal artery commences.

The supra-spinal artery.—This vessel (fig. 22. A. *w*, *x*, *y*), which has become a matter of much interest in our examinations of the vascular system, both in Myriapoda and Arachnida, is extended along the middle line of the body, immediately above the nervous cords, as far as the terminal ganglion in the last segment. At its commencement it is nearly equal in size to the great nervous cords along which it

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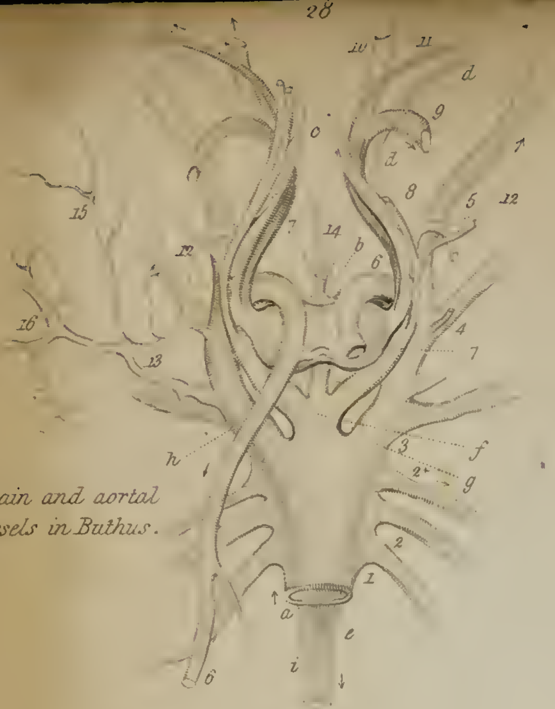
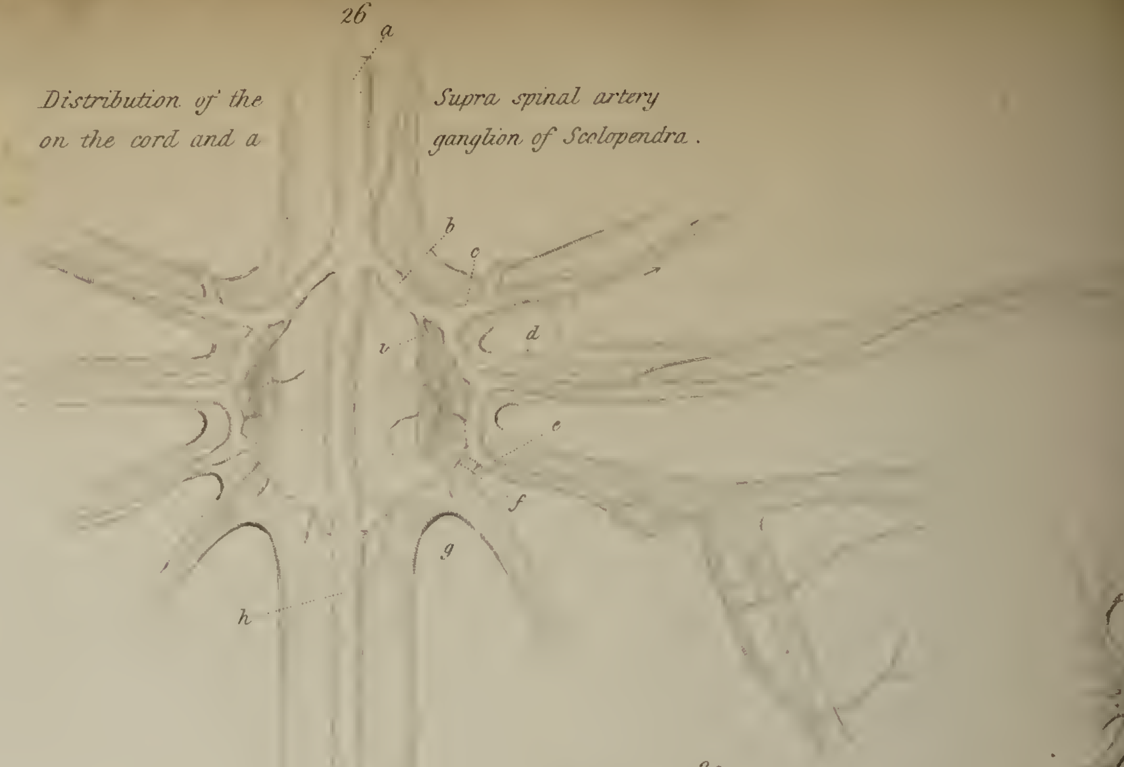


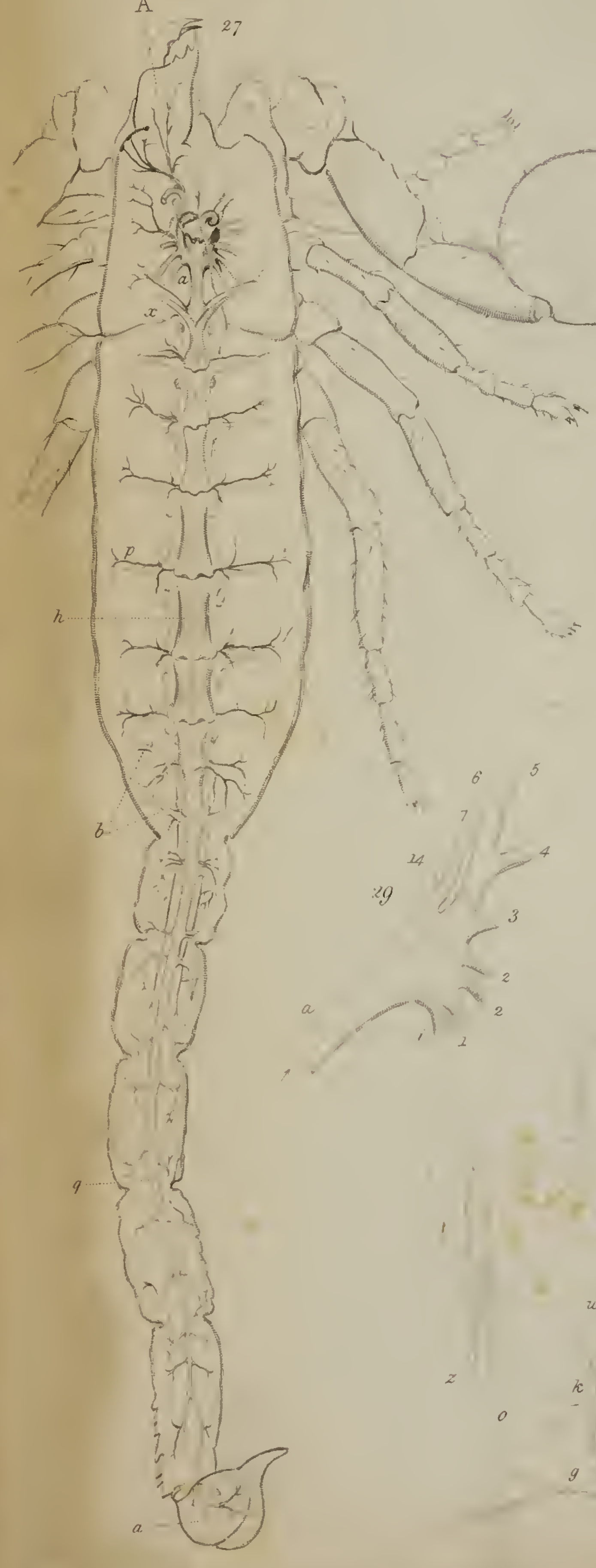
Brain and aortal vessels in Buthus.

26



Distribution of the Supra spinal artery on the cord and a ganglion of Scolopendra.

27



The heart with caudal artery, visceral arteries and distribution in cephalo thorax of Buthus Afer ? natural size.

29

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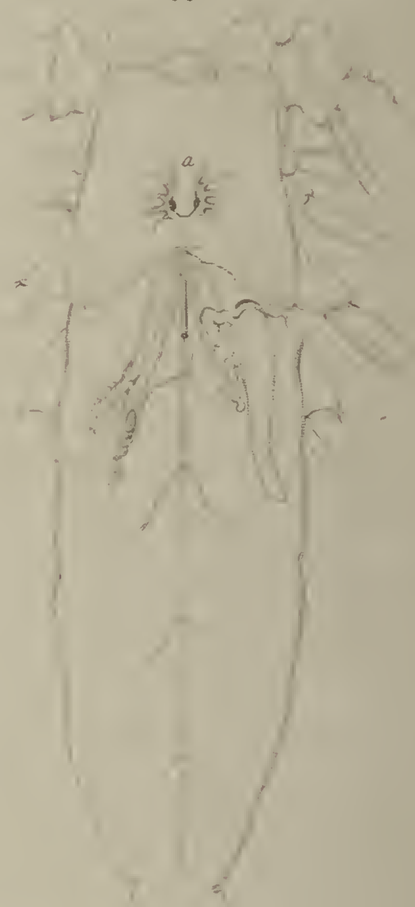

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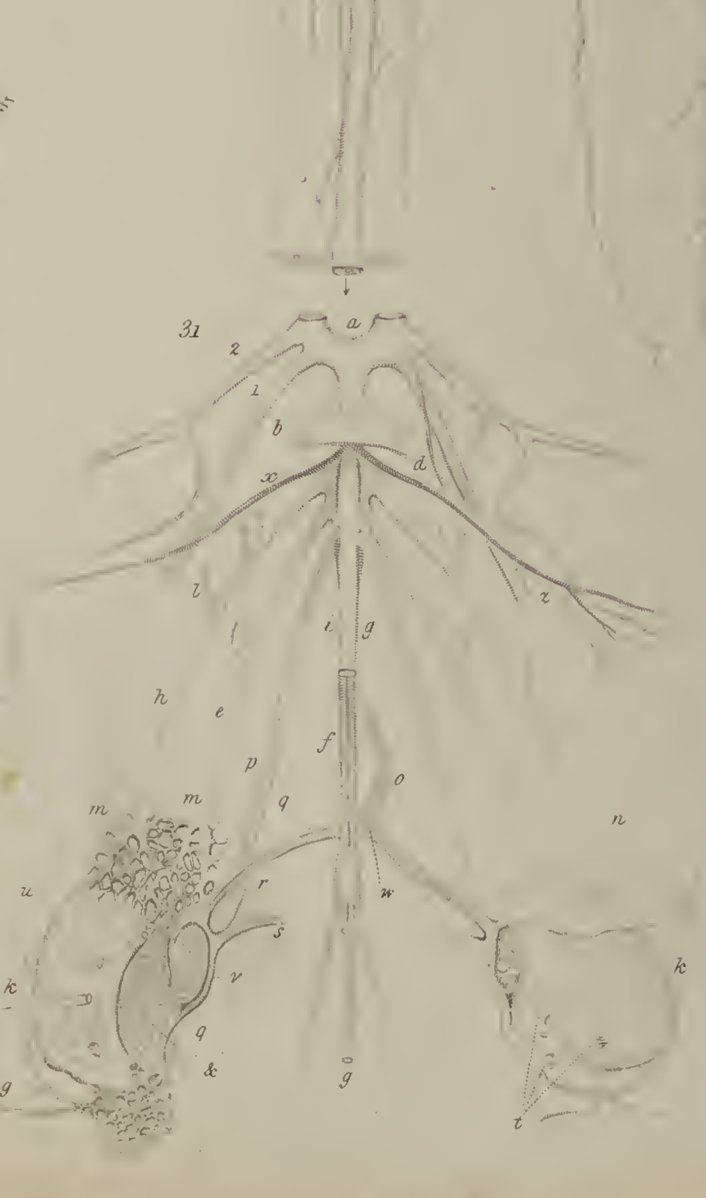
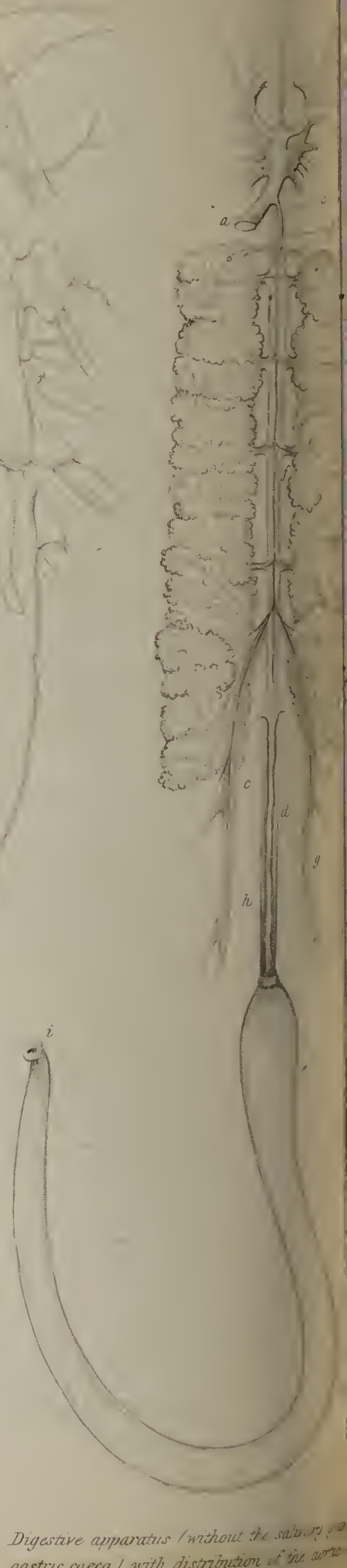


Portal System in Buthus Afer ? magnified 3 diameters.

32



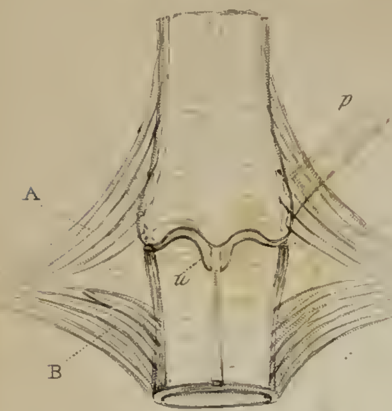
Digestive apparatus (without the salivary & gastric caeca) with distribution of the aortic visceral arteries in Androctonus. magnified 2½ diameters.

Circulatory System in Arachnida.

The Scorpion.

34

Superior external surface.



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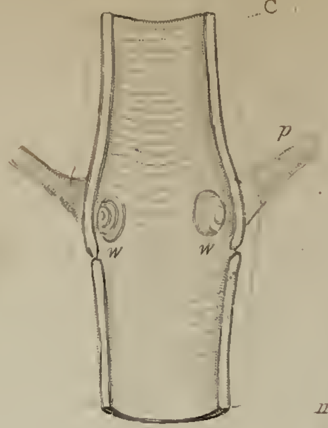
Internal inferior.



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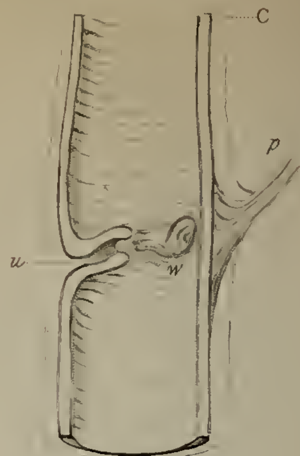
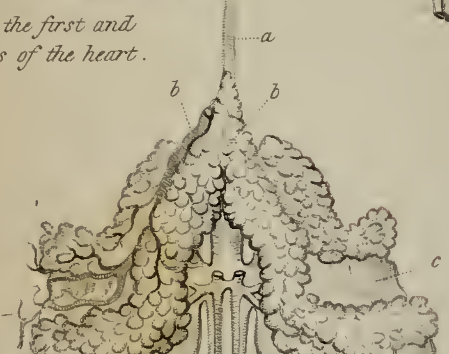
Anterior lateral.



Superior

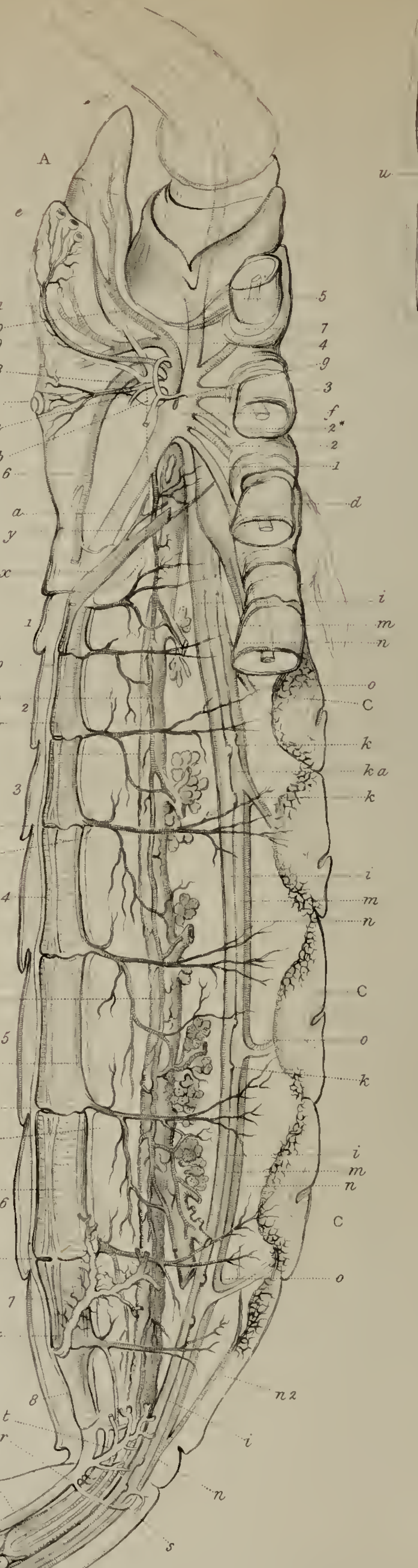
34 to 37. part of the first and second chambers of the heart.

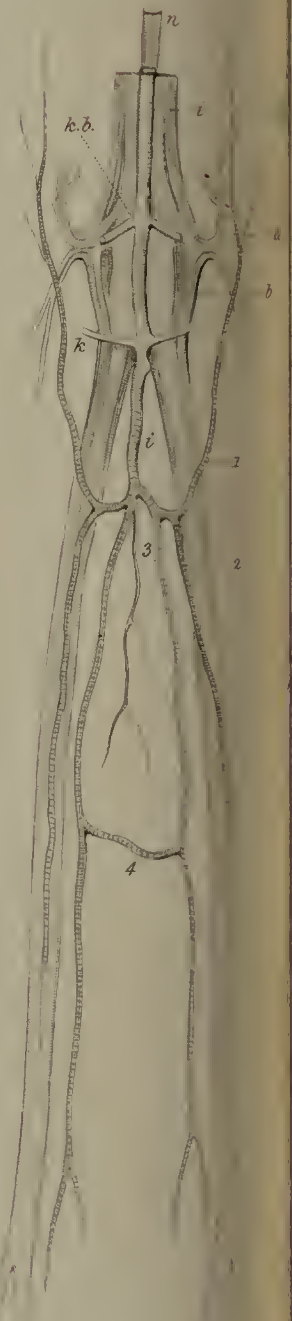
39



Anterior portion of the alimentary canal in the Scorpion. a. esophagus. b. salivary glands. c. lateral appendages of the thoracic portion of the canal (?) gizzard (?) D. commencement of the abdominal portion, with the lateral cæca and hepatic glands. e, and origin of the visceral arteries. z.

33



Termination of the supra-spinal artery ... last caudal ganglion in the scorpion.

Diagram of the Circulatory, Alimentary, Nervous, and Respiratory systems in Buthus, as seen on the right side of the body, magnified 2 diameters. h.q. the heart and caudal artery. p. systemic arteries. a. the aorta. i. supra spinal artery. m. nervous cord. n.o. sub-spinal vessel. A. antennal claws. B. e. the eyes. C. the pulmono branchiæ. D. the alimentary canal. E. the anal orifice. F. the poison glands.

G. Newport del.

is extended, becoming gradually smaller as it approaches the posterior segments of the body. The situation of this interesting structure, relatively to that of the nervous cord, the alimentary canal, and the other organs of the body, its connexion by vascular arches with the last ventricle of the heart, and the course of the blood which it distributes, all strongly remind us of its similarity to the great aorta of Vertebrata, and of the analogies which the whole of the vascular structures in these worm-like Articulata bear to those of Fishes and Amphibia, and the earlier condition of the fœtus in the higher animals. As it passes backwards along the cord, this spinal artery (Plate XIV. fig. 26. *a*) gives off a pair of branches (*b*) above the anterior part of each ganglion. These branches pass diagonally backwards and outwards, and on reaching the base of the first pair of nerves from the ganglion each gives off a large vessel (*c*) that takes the course of the nerve, and is distributed with it to the muscular and other structures. It then proceeds to the origin of the second, or principal nerve from the ganglion, and gives off a still larger branch (*d*). This, like the first, pursues the course of the nerve which is given to the great muscles of the legs, and is distributed with it to those structures. After this it turns a little backwards and gives off its third branch (*e*), which accompanies the corresponding nerve from the ganglion, and is given with it to the sides of the body. It is then greatly reduced in size, and gives off its fourth and smallest branch (*f*), which accompanies the fourth and smallest nerve, that is given exclusively to the tracheal vessels and parts concerned in respiration. From the origin of this branch to the fourth nerve, a very minute branch (*g*), the continuation of the trunk, proceeds diagonally backwards and inwards to the median line above the ganglion, to become united again with the great spinal vessel (*h*), and thus forms a channel back again into the great trunk for any residual small quantity of blood that is not passed into the other branches: the two principal vessels on each side thus form a complete vascular circle above each ganglion. Besides these principal branches each lateral trunk gives off on its inner side a small branch to supply the ganglion itself (*i*), and other minute vessels are given from the sides of the great artery to the cord. This is the distribution of the vessels from the spinal artery on each ganglion until it has reached the last segment of the body, in which it is scarcely more than one-third of its diameter at its origin in the third segment. Immediately above the last ganglion the artery itself is divided into two principal branches, with only a very minute median one between them. These branches take the course of the terminal nerves of the cord, and are distributed with them to the last pair of legs and the surrounding structures. These are the distributions of the arterial structures in the Myriapoda; some further idea of the extensiveness of which may be formed from the circumstance that the structure of the heart itself is extensively supplied with nutrient branches (fig. 18. *z*). A small artery passes along the median line of the heart, on its dorsal surface, included between the median suspensory muscles. This vessel gives off a pair of branches in each segment, about the middle of each chamber, and these are ramified on its upper surface. Some of the

minute ramifications of this vessel are extended backwards and outwards to the sides of the pericardium. In the peritoneum also there is an extensive ramification of circulatory and tracheal vessels, intermingled with each other in the most complex manner. Some of these vessels run parallel with the tracheal vessels, others are distributed to the structures covered by the peritoneum, and others pass through the peritoneal coverings and are distributed to the organs inclosed by them.

In the genus *Lithobius* the number of chambers to the heart, and of leg-bearing segments to the body, is reduced to fifteen. The form of the chambers and the general distribution of the systemic arteries closely resemble those of Scolopendra, but there are some peculiarities that deserve notice. The anterior chamber (fig. 23. 1. *p*) gives off three trunks, as in Scolopendra, but the two lateral ones, instead of passing forwards and then arching backwards, as in that genus, pass directly outwards, transversely to the chamber, and give off a single large trunk from their sides directly into the basilar joint of the great mandibles (c), at the posterior part of the short basilar segment of the head (B); and then unite beneath the œsophagus (*r*) in the same transverse manner, above the great subœsophageal ganglion to form the supra-spinal artery (*y*), which commences in this union without receiving a small median trunk from the inferior surface of the head, as in the Scolopendra. This artery passes backwards, in the middle line above, and between the two separated nervous cords (*y*, *y*), and gives off a pair of branches on the ganglions almost precisely the same as in that genus. It appears also to form some unions, both anterior and posterior to the ganglions, as in the Scorpions, with vessels that exist below the nervous cord, and which seem to belong to a portal system. All the blood sent through the aortic arches is returned along the under surface of the body in the spinal artery, from which it is sent off to the sides of each segment through the lateral trunks, the divisions of which take the course of the nerves to the muscles, to the legs, and to the respiratory organs. Posterior to the fourteenth pair of ganglia in the nervous cords the spinal artery (fig. 24.) is divided into two branches (15.) which pass backwards, side by side, as far as the anterior margin of the terminal ganglion, at the front of which (*z*) each gives off a branch that passes laterally backwards and outwards, and the main trunk then pursues its course over the ganglion on which it gives off a second branch (*x*) which accompanies the great nerves from this ganglion to the posterior pair of legs. The remaining portion of each division of the spinal artery then divides into several small branches, which accompany the nerves from the *caudal ganglia* (17, 18.) to the external organs of generation and the rectum. The supra-spinal vessel in Lithobius is accompanied on each side by ramifications of tracheal vessels, distributed along the sides of the cords. From these vessels numerous ramifications are sent to the ganglia, as in insects, and are distributed through their structure. When a tracheal vessel is given off behind a ganglion, it sends a branch forwards beneath the lateral vessels from the great spinal artery, and it is then divided on the upper surface of the ganglion into very minute ramusculi, some of which

penetrate the substance of the ganglion accompanied by the arteries given to it from the lateral branches from the spinal artery.

The small median cephalic artery (fig. 23. A. *q*), given off from the heart with the aortic arches to the head, passes along the œsophagus to the posterior pair of muscles of the pharynx, behind which it gives off its second pair of branches. These pass downwards to the maxillæ and internal parts of the mouth and unite beneath the pharynx, but do not send any vessel backwards to join the great spinal artery at its commencement and junction with the aortic arches, as in the Scolopendra. The small median trunk then passes beneath the brain, and is divided on the front of it into two pairs of branches, one of which passes laterally to the organs of vision, and the other proceeds forwards on the inner side of the great nervous trunk to the antenna. I have not yet ascertained to what distance this vessel is extended in the antenna of the perfect individual, whether throughout the greater part of the organ, forming a series of loops in the joints, or whether the whole trunk is returned backwards across the third joint of the antenna, in the course of the current of the blood seen in this part of the head in the young Lithobius. It is quite certain that the course of the blood backwards in the antennæ and head is in a vessel on the external side of the antenna, both in Lithobius and Scolopendra. The existence of this vessel I have repeatedly traced in Scolopendra, backwards from the antennæ, beneath the optic ganglia, to its union with a small median trunk beneath the œsophagus that passes backwards between the nervous cords to the junction of the aortic arches and spinal vessel. The course of the blood in the antenna in the young Lithobius is always forwards on the inner side, and backwards on the outer side of the organ.

In the *Scutigeridæ* the circulatory system affords a still further proof of the principles already advanced, that the complete development of every structure is by the union of two or more original parts. In the Iulidæ we have already seen this very principle illustrated in the same animal, in different stages of its growth, in the union of two chambers of the heart in each moveable double segment; and there is a further illustration of it in the permanent structure of the heart of the Scutigeridæ. In this family the number of chambers is still fifteen, as in Lithobius, but every alternate chamber (fig. 25.) is reduced both in size and extent. This reduction of length had already begun to take place in Lithobius, in which the dorsal plates of the body are alternately longer and shorter in the different segments, to the respective lengths of which the chambers of the heart were begun to be reduced. This is a condition preparatory to the union in pairs, first of the dorsal plates, and afterwards of the chambers of the heart. In the Scutigeridæ the dorsal plates are already united, and form but eight moveable coverings, one to each pair of segments, which still remain distinct on the ventral surface of the body. But although there are still sixteen chambers to the heart, the changes commenced in Lithobius are carried still further in this genus, and each alternate chamber is very much smaller and shorter than the one next before it, and covered by the same dorsal plate. But although the

union of the chambers has actually commenced, it is yet very imperfect, and the original divisions between them are still evident, and the systemic arteries pass off from their sides as in their imperfect state of development. But very little blood enters at the auricular orifices, which still exist in these unions. The chief part now enters through the large auricular orifices of the chambers in the middle of each dorsal plate. These are very distinct, but are placed more transversely to the heart than in Scolopendra, corresponding to the more obtuse form of each chamber, and the more compact general form of the whole heart. Here then in the gradual reduction of the number of the chambers, their compact form, and the shortening of the organ, we trace the stages of the formation of the heart in insects, in which there are seldom more than eight chambers.

The minute anatomy of the heart exhibits also a more perfect state of development than in any of the other Myriapoda. The two tunics of which it is composed are united more firmly together, the longitudinal fibres are less distinct than the transverse, which are very strong and powerful, and distinctly marked in the external tunic. The great contractile power of the heart seems to exist chiefly in the transverse fibres, the longitudinal contractions being greatly influenced by the suspensory muscles and the *alæ cordis.*

The distribution of the vessels in *Scutigera* closely resembles that of Lithobius; three principal trunks being given off from the anterior chamber of the heart, immediately behind the head, which has assumed in this family the compact form of true insects, the great basilar segment, to which the mandibles or foot-jaws are attached in Scolopendra, and the other genera, reduced to a very narrow short segment in Lithobius, being now united to the chief portion of the head in this genus. The aortal arches, in consequence of the union of these segments, pass around the œsophagus to unite beneath it, immediately behind the occipital portion of the head, while the small median trunk is situated entirely within this region of the body, thus affording further proof of a higher grade of development than that which we have already seen in the Chilognatha.

The circulatory system in Arachnida has already engaged the attention of several anatomists, but hitherto has been only very imperfectly understood. Treviranus in 1812 described it vaguely, and first noticed the structure, now described as the supra-spinal artery, as part of the nervous system, and considered it a peculiarity of the nervous system of the Scorpion. Müller, as before stated, noticed the same structure in 1828, but regarded it as a ligament. Both these anatomists entirely overlooked the extensive distribution of vessels from the anterior extremity of the heart in the cephalothorax.

The Heart.—The heart (Pl. XIV. and XV. figs. 27 and 33. *h*) of the Scorpion is a strong muscular organ, extended along the middle of the back, from its continuation with the great caudal artery (*q*), in the last segment of the abdomen, to the commencement of the aorta (*a*) at the diaphragm (*x*), that divides the abdomen from the

cephalothorax. The aorta descends obliquely forwards and downwards, between the muscles, to the œsophagus, on which it is spread out, behind the brain, into several large vessels, the two posterior of which are united beneath the œsophagus, and give origin to the great spinal artery (*i*)—the structure above noticed. In the dorsal part of its course the heart is divided into eight separate chambers, which are wider and stronger in proportion to their length than in the highest of the Myriapoda—the *Scutigeridæ*. They are more muscular and compact in proportion to the greater quantity of blood to be transmitted through them, and the force with which it is necessary to be propelled. The form of each chamber (Pl. XV. fig. 34.) is somewhat heart-shaped, being slightly contracted in its middle portion, and enlarged at its posterior. Each chamber has two auricular openings (*u*) for the passage of the blood, placed very close to the median line of the heart on its dorsal surface; and it gives off at its inferior lateral angles a pair of large arterial vessels (*p*), the systemic arteries, which distribute the blood downwards to the viscera, and to the dorsal and lateral surfaces of the body. These are the vessels imperfectly noticed by Treviranus. Each chamber is also provided at its sides, as in the Myriapoda and insects, with two sets of muscles, the *alæ cordis*. The anterior and largest pair of muscles are attached to the anterior part of each segment, and pass diagonally forwards, and the posterior, the proper retractor muscles of the chamber, to its posterior angle, and are directed backwards, leaving between the two sets of muscles a passage for the vessels. Of the eight chambers that form the heart in the Scorpion, the posterior two are the smallest, and are situated in the seventh, or last segment of the abdomen. The eighth chamber is very imperfect, and is continuous with the caudal artery, which passes backwards to the post-abdomen, or tail (*q*. *q*.). The sixth chamber is the largest and most powerful of the whole organ, and seems to correspond to the two chambers in the nineteenth and twentieth segments of the Scolopendra, and which, in that animal also, are the largest. Each succeeding chamber, from the sixth to the anterior one (*t*), at the termination of the heart in the aorta, as it enters the thorax, is shorter, and narrower than the one next behind it, and the systemic arteries (*p p*) are smaller than those of the posterior. The structure of the chambers internally differs considerably from that of the chambers in the Melolontha, as described by Straus Durckheim. Each valve or division between them is formed by a reduplication (fig. 36. *u*) of the whole muscular structure of the dorsal surface of the organ. This reduplication, which is chiefly on the upper and lateral surfaces, is very imperfect on the under, and in some of the chambers is entirely absent on the under surface. It is extended about midway into the interior, which it divides more completely than in its less perfect state of development in the young Myriapoda. It is most complete in the sixth abdominal segment, between the largest chambers of the heart. In the middle ones it is extended inwards and forwards, in the form of a broad nipple-shaped protuberance, the orifice of which is opened behind in the middle line. This protuberance (fig. 37.) is situated above, and a little behind, the two large outlets of the systemic

arteries (w), through which the blood is transmitted to the sides of the segments. The reason for this imperfect structure of the valves may perhaps be explained by the fact that the blood is distributed from the heart in the Scorpion in opposite directions, partly backwards to the tail, but chiefly forwards and outwards to the head and sides, as in the Myriapoda, and hence it may be necesary that a reflux of the blood should not be entirely prevented, as may be required in those instances in which the whole current is in one direction. This also may be the reason for the valves being formed more transversely, and less completely than in insects. The structure of the organ is exceeding thick, opake, and muscular. It is formed of two layers of fibres, longitudinal and circular in each layer, the most powerful of which are the latter. On its internal surface it is smooth, and lined by an exceedingly delicate membrane, through which the strong circular fibres are distinctly marked. It is by means of these that its most powerful contractions are effected, the auricular action being chiefly the result of the relaxation of these fibres, assisted by the reactions of the lateral muscles.

At the junction of the heart with the aorta (figs. 27. 33. t), as it enters the thorax, the last pair of lateral muscles descend forwards, on each side, into that region, and thus confine it above the diaphragm (x). Immediately anterior to the origin of these muscles, close to its junction with the aorta, the heart gives off its anterior pair of systemic arteries (y), which ramify on the diaphragm and in the posterior parts of the thorax.

Distribution of the Aorta.—The *aorta* is short, thick, and smooth on its external surface, without lateral muscles, or internal divisions into chambers, but there are indications of an obliterated chamber at its commencement. It descends obliquely forwards and downwards, and after passing beyond the great median arch of the thorax, to which many of the muscles of this region of the body are attached, it is widened, and rests on the upper surface of the œsophagus, and gives off the vessels to the head, to the organs of locomotion, and to form the great spinal artery; at this part of its course its distribution is exceedingly interesting. I have already attempted to show the remarkable uniformity of principles on which the nervous and circulatory systems are developed. In no instance is this uniformity more curiously illustrated than in the distribution of the aorta to the limbs and to the head in the aggregation of segments that constitute the cephalothorax. We have seen that vessels are given off from corresponding parts of the chambers of the heart both in the Myriapoda and the Scorpion, and that these vessels, *the systemic arteries*, are given to precisely similar parts in both. In the Myriapoda the anterior pair of these vessels form a vascular collar around the œsophagus in the posterior region of the head, and this also is the case in the Scorpion. The median continuation of the vessel beyond this collar in the Myriapoda is given to the head, to the brain, optic nerves, antennæ and internal parts of the mouth; while the external parts of the manducatory organs, the great foot-jaws or mandibles, are supplied from the vascular collar, or from parts immediately connected with it. Now, notwithstanding the aggregation of all these parts

together, as well as the proper organs of locomotion, the trunks of the arteries still preserve their original distinctness, and enable us to identify the organs and parts of the head in the Scorpion with corresponding structures that exist under other forms, although endowed with similar functions, in the more distinctly developed head of the Myriapodes and insects.

When the aorta (figs. 27. 28. 29. 33.) has descended on the alimentary canal, at a short distance behind the brain, it gives off its second great trunk backwards (1.) to the posterior pair of legs. The first trunk (*i*) having passed downwards, unites with its fellow of the opposite side below the œsophagus to form the supra-spinal artery, the great systemic continuation of the aorta backwards, into the abdomen, the distribution of which I shall presently describe. The third trunk (2.) is given to the penultimate pair of legs, and the fourth (2*.), which is smaller than the others, is specially distributed to the middle portion of the thorax. Opposite to this pair the aorta is considerably widened, and is separated into three great divisions (*f*, *g*, *h*). The middle one of these (*f*), which also is divided into three branches, still preserves its original distinctness, and constitutes the cephalic artery and arterial vessels of the head above the œsophagus, while the two great lateral divisions of the aorta are given at the sides and below the œsophagus to the two remaining pairs of legs (3, 4.), and the great prehensile claws (5.), the analogues of the foot-jaws in Scolopendra, and the mandibles of Iulus and of insects. In this mode of origin and distribution, we obtain a clue to the identity of the special organs of the head in the Scorpion with those of the more perfect Articulata, and also with those of the mouth in the Chilopoda, the foot-jaws, which many naturalists have regarded as not forming part of the organs of manducation. The size of these prehensile organs in the Scorpion requires that an immense volume of blood should be supplied to them in the least difficult manner, and this is effected by the trunk of the great artery being extended into them at an angle very little diverging from the direct line of action of the heart and aorta, so that the blood is necessarily propelled onwards through their extensive ramifications of vessels, with as little resistance as it is passed into those of the head. Before the great lateral artery enters the prehensile organs, which it always does on the inner side of the great nervous trunk, it gives off a large branch that ascends in front of the brain (6.), and forms a transverse anastomosis with the middle cephalic artery (14.), and also with its fellow on the opposite side; and then passing upwards, it is distributed to the large salivary glands (fig. 39.), to the muscles on the upper surface of the thorax, to the diaphragm, and to the anterior parts of the dorsal surface of the abdomen*. This then we may regard as the proper distribution of the supraœsophageal blood-vessels of the thorax.

Cerebral Arteries.—In the distribution of the *cerebral arteries* we find that the cephalic artery (Plate XIV. fig. 28. *f*), which we saw in the Myriapoda divided into three

* These two vessels are often united into a single trunk on the front of the brain, and are then divided again and distributed as described.

branches, which are given to the brain and the organs of sense, is distributed in the same manner in the Scorpion. The middle branch (14.)* goes forward to the brain (*b*), to which it gives some very fine vessels, and then passes beneath it, to be distributed above the palate, on the anterior part of the head, where it is again divided into three small trunks (14.), above the small origin of the vagus nerve. It also forms an anastomosis, as already stated, with the divisions from the great lateral artery from the prehensile organs, and thus assists to complete a vascular circle around the brain (*b*), the centre of the animal functions. The two lateral branches of the cephalic artery (7.) pass, one on each side of the brain, giving off a large vessel (8.) to the great optic nerve (*c*), with which it ascends to the surface of the head, divided into many minute ramifications, that supply both the tegument and the chief organs of vision (B.). After this the lateral cephalic artery bends inwards on the front of the nerves, to the middle line, on the inside of the flexor muscles of the small prehensile organs (A.), the analogues of the antennæ, and it is then divided into two principal branches (9. 10.), having first given off one (12.) that, passing backwards and outwards, forms two anastomoses with branches from the great subœsophageal division of the artery (13.), from which other branches are distributed. Some of these ascend to the tegument that covers the muscles of the second pair of legs, while others (16.) pass downwards among the muscles of the thorax. The largest division (9.) of the lateral cephalic artery then passes upwards, and is given to the great muscles of the antenna on the dorsal surface, while the other enters the basal joint of the antenna on its inner side, and is again divided into two branches which are given to the two prehensile divisions of this organ (A.). Besides these there is a third and smaller branch (11.) given off very near to that (8.) which goes to the principal eyes. This branch in like manner passes upwards and inwards with the nerves of the smaller lateral eyes (*d*), which arise by a single trunk from the same part of the brain as those which are placed on the middle of the cephalothorax (*c*).

Thus then in the origin, and in the uniformity of distribution of the vessels and nerves of the head, we are enabled to identify the small prehensile organs on the front as the analogues of the antennæ of insects, and which, although so remarkably altered in form from a simple, elongated, many-jointed organ, to one of a prehensile character, still retain the same primary function, that of touching and feeling as in their less complicated structure.

This arrangement and identification of the structures in the Scorpion serves still farther to illustrate that admirable uniformity of design on which all organized bodies are constructed. The distribution of the blood-vessels in these Invertebrata is as uniform in its plans, and as precise in its character, as in the blood-vessels in the higher animals. The large arterial trunks always accompany the principal trunks of the nerves, especially at their origin from the brain and cord. So likewise the arterial vessels invariably exhibit a strong fibrous texture, more especially those which

* This branch is very frequently absent in the Scorpion.

carry out the chief currents of the blood from the heart itself, the systemic arteries, and the aortic branches; while on the contrary, like the veins of the Vertebrata, those which bring back the blood in the principal organs do not always pursue the course of the nerves, nor are of the same dense elastic texture. They are usually exceedingly delicate, membranous and transparent; and this is more especially the case with those which, covered by the peritoneum, bring back the blood round the sides of the body to the heart. An exception however must be made to a system of vessels in the Scorpion, which, although performing the function of veins in collecting the blood that has been distributed through the system by the arteries, partake also of the character of arteries in their texture as well as in their function of propelling the collected blood into the branchiæ for the purposes of respiration. This, which may be regarded as a *Portal System* of vessels, is in close connexion with the subœsophageal distribution of the arteries which pass backwards into the abdomen from the vascular collar formed by the aorta around the œsophagus.

Arterial Vessels of the Abdomen.—The *vascular collar* which surrounds the œsophagus analogous to the *aortic arches* in the Myriapoda, forms the great *supra-spinal artery* (fig. 31. *a. i.*), which may be regarded as the *aorta descendens.* This great vessel is formed by it immediately anterior to the middle bony arch (*b*) of the cephalothorax, and passes backwards above the nervous cord (*s*), in the median line, beneath the arch, to which it is slightly adherent by fibrous tissue. It was this circumstance, probably, which led Professor Müller, who observed it in 1828, to regard it as a ligament. It is extended backwards (Plate XV. fig. 33. *i.i.i.*) along the whole nervous cord (*m.m.m*) to the terminal ganglion of the fourth segment of the tail, gradually lessening in diameter, and giving off on its under surface a single short trunk (*k*), both anterior and posterior to each ganglion. These short trunks pass downwards between the nervous cords (*m*), and unite with the system of portal vessels which extends beneath them (*n*). The supra-spinal artery does not give off any other branches in its course through the abdomen until it arrives at the terminal ganglion; so that these azygos branches, which seem to distribute very minute vessels to the ganglion itself, and to the two nervous cords as they pass between them, may be regarded as analogous to those which we have seen given off from the supra-spinal artery on the ganglia in the Myriapoda; while their continuation with the vessels of the portal system beneath, with which they pass outwards, may represent those which are also continued outwards along the nerves in the same class. When the artery has reached the terminal ganglion in the tail (Plate XV. fig. 38.), it gives a descending branc has usual to unite with the subspinal vessel (*n*) beneath it, and then becomes a little expanded, and produces on each side a small branch on the front of the ganglion (*k. b*), precisely similar to the first of the terminal branches in the Myriapoda. This accompanies the lateral pair of nerves outwards to their distribution in the lateral muscles and the surrounding structures. The trunk of the artery then passes over the ganglion and immediately gives off another pair of branches (*b*), which seem first to form an

union (*k*) at the roots of the nerves with the subspinal vessel beneath, and then pass outwards to the sides of the segments. Immediately after this a second median branch is united behind the ganglion with the subspinal vessel, and the main trunk passes on for a short distance between the terminal nerves of the ganglion, and is then divided into two branches which take the course of the terminal nerves. Each of these divisions of the artery gives off a branch which is distributed in part forwards (1.) to the under surface of the colon, and part backwards to the same structure (2.). The two terminal divisions of the artery (3.) then pass backwards with the terminal nerves and anastomose by a short transverse trunk (4.), and each again divides into two branches immediately before the nerves also are divided, at the posterior part of the fourth segment. They then accompany the nerves to their ultimate distribution, and are always divided immediately before any division takes place in the nerves. This is invariably the manner in which the arterial vessels accompany, and are divided with, the nerves, and proceed with them to their ultimate distribution.

Having traced the distribution of the arterial vessels from the anterior extremity of the heart, it remains now to follow those of the posterior, which afford some curious peculiarities. The last two chambers of the heart which are situated in the seventh segment of the abdomen, are greatly reduced in size, and constitute the origin of the caudal artery, and seem to be the means by which part of the current of blood is directed backwards to the tail. Each of these chambers receives its venous trunks (figs. 27. *b*. 33. *t*.) in a direction more transversely backwards than the other chambers, so that the influx of the received blood is directed backwards. The vessels which convey it ascend between the muscles and the peritoneum, as well as around the sides of the segments. The visceral arteries from these chambers (*p*) are also altered in their direction. Instead of passing laterally and forwards, they give off only a small trunk forwards and to the sides of the segments, while their principal trunks are directed backwards. Those from the seventh chamber proceed as far as the posterior part of the first caudal segment, at the sides of the colon, and are specially distributed to the terminal alimentary cæca, while the eighth chamber (*p*, *q*) sends off only a single artery on its under surface. This is divided into three branches, two of which pass, one on each side, to the terminal cæca, while the third proceeds in the middle line, beneath the caudal artery, as far as the middle of the second segment, where it is divided into branches which are given to the muscular structure of the colon. When the caudal artery has entered the first segment of the tail it gives off on each side a plexus of four vessels, two of which are distributed forwards and laterally; the third backwards, to the great flexor muscles on the dorso-lateral surface of the segment; and the fourth (*r*), passing round the sides, between the peritoneum that covers the muscular structnres and the colon, meets with the nerves that are passing upwards from the ganglion of the cord, and pursuing their course downwards unites beneath the ganglion (*s*) with the caudal portion of the subspinal vessel (*n*) that is passing inwards to the abdomen. At the commencement of each segment of the tail a pair of vessels

passes in this manner from the artery, on the dorsal surface around the colon, to unite beneath a ganglion of the cord with the subspinal vessel on the ventral surface; thus forming a series of four vascular collars (*r. r. r. r.*) around this portion of the alimentary canal, one in each segment, at its commencement nearest the abdomen. At the distal end of each segment a second set of vessels is given off, but these are given solely to the muscular and other structures, and do not form any anastomoses with the subspinal vessel.

Besides the arteries already described, there are others which deserve to be regarded as proper *visceral arteries*. These originate from the inferior surface of the aorta before it spreads out on the œsophagus into great branches. They come off from the under surface of the aorta, either in pairs, as in the genus *Buthus*, Leach (fig. 33. *z*), or as a single trunk, as in *Androctonus*, Koch (fig. 32. *c*, *d*), as we have seen in the caudal vessels. They are given specially to the alimentary canal and the liver, to which they give off a branch on each side (*f*), opposite to each junction of this viscus with the alimentary canal (*d*). They also anastomose extensively along the whole of the abdomen with branches from the proper systemic arteries, and are continuous with branches which pass forwards on the alimentary canal from the trunks of the systemic arteries from the great chamber of the heart in the sixth abdominal segment. The beautiful uniformity of the principles of development is thus further illustrated in these vessels. Like the great divisions of the aorta these also are modifications of the systemic arteries, the primary vessels of the segments, and are specially given to the alimentary canal at its anterior extremity, as the systemic arteries in the Myriapoda are to the hepatic appendages of the same structure at its sides and posterior extremity.

The portal system of vessels (figs. 30, 31.) is situated chiefly below the nervous cord on the ventral surface of the body, and is the means by which the blood is collected and conveyed to the branchiæ, from which it seems to be returned to the system, after circulating through the organs, by means of a large sinus or vessel at their posterior superior angles. Behind the bony arch of the thorax (fig. 31. *b*) there is a hollow fibrous structure (*d*) that closely surrounds the cord and nerves, as in a sheath, but the precise nature of which I have not fully ascertained. It seems to form a kind of sinus, from the posterior part of which a small vessel passes backwards, which, joined by anastomoses from the supra-spinal artery, forms the commencement of the subspinal vessel (*g*); and it gives off two pairs of vessels at its sides. The first (*h*) and second (*e*) pair of these efferent vessels, covered by the thick peritoneal lining of the abdomen (*n*), send the blood in a diagonal direction backwards to the first pair of abdominal branchiæ (*k*). The first pair of these vessels originate close to the folds of the diaphragm (*x*). They pass backwards and outwards into the abdomen, and are joined in their course by numerous small vessels (*l*) from the sides of the segments; and immediately anterior to the first pair of abdominal branchiæ are each divided into two branches (*m*), which are again divided and subdivided into

a multitude of anastomosing vessels before they are distributed on the branchiæ. These branchiæ also receive the second pair of efferent vessels (*e*), which, like the first, pass diagonally backwards from the fibrous structure to the inner side of the branchiæ, on approaching which they are divided, like the other pair, into two branches (*m*), which are subdivided and anastomose with the divisions of the first pair. The whole form a most intricate web of anastomosing pulmonic capillary vessels before they are distributed on the anterior part of the branchiæ. We have thus a complete distribution of the blood to the pulmono-branchiæ in the anterior part of the abdomen. There is a similar but less perfect distribution in the posterior. Besides the vessels from the sides of this fibrous structure, which in reality may be regarded as a great *vena cava*, there is also the single vessel extended backwards (*g*) from its posterior extremity in the median line beneath the nervous cords (*f*) into the abdomen. This vessel was formerly described by me*, before I had traced its origin, as the *subspinal vessel.* It is extended backwards beneath the nervous cord and receives a small vessel from the supra-spinal artery above it, both anterior and posterior to each ganglion. Immediately after it has entered the abdomen it gives off a single trunk (*o*), which, joined by a minute vessel from the supra-spinal artery (fig. 29. *z*), passes outwards and downwards on the right side of the cord and a little backwards, lying loosely in the under surface of the segment, and at length becomes slightly enlarged (*o*) and is divided into two branches, which also are enlarged at their origin; and the whole form between them in the middle line a triangular dilatation or *small vena cava* (*w*), in which the blood may be accumulated. These branches then pass diagonally outwards and are given one on each side to the anterior part of the second pair of branchiæ, each being first divided into numerous anastomosing capillary vessels, as in those already described. But before this division takes place each branch receives the double trunk of two other venous branches (*r*, *s*) that convey the blood backwards and outwards from the middle inferior surface of the abdomen. These unite with the first branch on the inner side of the great vertical muscles (*v*) that mainly assist in the respiratory action of each segment; after which the branch passes backwards to its distribution, accompanying the great nerve of the segment (*p*). When the subspinal vessel has given off this first pulmonic trunk it passes onward, and opposite the middle of the first pair of branchiæ gives off a second, which, like the first, is extended backwards for a short distance, lying loosely in the segment. This second trunk is then dilated and divided into two lateral branches like the first, and these, after receiving other vessels from the inferior surface of the segments, are given to the second pair of abdominal branchiæ. At a little distance further on, when it has arrived at the second ganglion of the abdominal cord, the subspinal vessel is itself a little dilated, and is divided into two lateral branches which pass outwards in close approximation with the nerves from the ganglion; and having received an accession of venous trunks as before, these branches are given to the third pair of branchiæ. After this the sub-

* Medical Gazette, March 10, 1838, p. 971.

spinal vessel becomes very much smaller, and about midway between the second and third abdominal ganglia sends off a pair of smaller branches, which are given in like manner to the posterior part of the same branchiæ. It then continues its course as a very minute trunk to the third ganglion. At this point the direction of the lateral vessels given off from it is altered (fig. 33. *n.* 1). Instead of passing laterally backwards they are now directed outwards and forwards, to distribute the blood to the anterior part of the fourth pair of branchiæ. This altered direction of the vessels is necessary in order to convey inwards to the body the blood that is passing forwards along the subspinal vessel in the tail to be aerated in the posterior branchiæ of the abdomen before it is again transmitted to the heart. That this is the case is proved by the fact, that a single median trunk (*n.* 2.) is given off from the under surface of the subspinal vessel beneath the ganglion in the first caudal segment. This trunk is directed forwards into the seventh or terminal segment of the abdomen, lying loosely like those which are directed backwards in the anterior segments. When opposite to the posterior part of the fourth pair of abdominal branchiæ it is dilated and divided into two branches, which together form a dilatation like the anterior ones before they are directed outwards and are joined by other venous trunks and distributed over the branchiæ. This is the mode of distribution of these vessels in the great Scorpion, ***Buthus afer***, Leach, but a slight variation is found in some other species. Thus in the specimen formerly* examined, ***Buthus costimanus***, Koch, or a species nearly allied to it, instead of a pair of branches given off from the subspinal vessel midway between the second and third abdominal ganglia, I found an azygos vessel given off beneath the latter, and which having passed forwards, midway between these ganglia, was then divided into lateral branches like those at the anterior part of the body.

This peculiar distribution of the subspinal vessel in the abdomen enables us to understand a fact that seems at first very difficult of explanation; viz. that the branches from the caudal artery on the dorsal surface of the tail do not anastomose with the spinal artery (*i*) that lies above the cord, and in which the course of the blood, as we have already seen, is from before backwards, but with the subspinal vessel beneath it (*n*), in which the course of the blood is inwards to the abdomen, precisely that of the dorsal artery; so that the unemployed blood from this structure, and that which has become venous, is collected as it returns from the tissues by the subspinal vessel, and intermingled together before it is transmitted to the branchiæ.

Structure of the Pulmono-branchiæ.—Professor Müller† has already accurately described the pulmono-branchiæ as formed of a multitude of closely approximated, thin, double lamellæ, which communicate by a small orifice in each with the external air admitted into a common cavity through the spiracle on the surface of the body. The blood distributed through these lamellæ is brought into contact with the air in their interior through their membranous structure. The minute anatomy of these lamellæ, and the manner in which they are permeated by the blood, afford some

* *Loc. cit.*

† Meckel's Archiv, 1828.

points of interest. Each side of these double lamellæ is formed of an exceedingly delicate and apparently structureless double membrane, which include within it a parenchymatous tissue, formed of single vesicles or cells, in which I have been unable to detect any nuclei. These cells exhibit the appearance of simple bodies, from which it might well be conceived that vessels might be formed. In some places these vesicles are arranged more in distinct series, and are also slightly elongated. The whole parenchymatous tissue of the lamina is made up of these cells, which are larger and more elongated, and assume a slightly conical appearance near where the air enters at the base of each plate, in which part these cells are nearly uniformly distributed within the double membrane. But in the upper or more convex portion of each lamina, numbers of these minute cells are aggregated together in numerous, irregular, rounded patches, which thus produce a tuberculated or glandular appearance in the lamina. These aggregations of cells are more thickly interspersed through the structure of the lamina the nearer they are to its convex margin, where I have sometimes seen what I believe to be delicate but exceedingly indistinct vessels penetrating the lamina, but which could be followed only for a very short distance into it among the cells. The convex margin of each lamina is however bounded by a delicate but distinct vessel, which seems to form the means of intercommunication between the anastomosing net-work of vessels distributed over the branchiæ and the structure of the laminæ, since the delicate evanescent vessels traced into the laminæ are derived from those which bound their convex margin. I have also observed vessels extended from these marginal vessels on the laminæ, which I regard as the anastomoses between these and those which cover the whole branchiæ, and distribute the blood from the portal branches.

It has already been stated, that at the posterior part of the inner side of the branchiæ, on their superior internal margin, where the laminæ are covered by the thick membrane and peritoneum that covers the common cavity of the branchiæ, there are several small orifices (fig. 31. *t*), the commencement of vessels which afterwards, when collected together, form the larger channels that convey back the blood to the heart. At the superior angle of each lamina of the branchial plates there is a small sinus that opens into a larger one, formed on this border of the common cavity by the whole of the laminæ, which from its direction backwards appears to communicate with the orifices. From these facts it would appear that the blood permeates the nucleated parenchymatous tissue of each double lamella, and is brought into contact with the air, when the branchiæ are inflated during respiration, by endosmosis through the membranes, and then, collected in the sinuses at their base, it passes out again through the orifices and vessels at their superior border, to be returned again to the heart. These vessels form delicate vascular trunks or sinuses which pass around the sides of the body in the posterior part of each segment, and gradually enlarged by communicating with other vessels in their progress, pour their contents into the heart at the auricular orifices (*u*) on its dorsal surface.

The orifices in the common cavity of the branchiæ (fig. 31. §), which communicate with the interior of the lamellæ, are largest in the anterior and smallest in the posterior ones. The cavities of all the branchiæ communicate directly with each other by a short narrow passage, so that the whole on one side of the abdomen forms one common cavity or lung-like organ, like the large tracheal vesicles in the abdomen of perfect insects, and thus ensures an uniformity of function at each act of inspiration throughout the whole body.

Nutrition of the Branchiæ.—Besides the vessels already described, the branchiæ are supplied with *arterial branches* apparently for the nourishment of their tissues. The first arterial vessel is derived from the supra-spinal artery while passing over the *vena cava.* This vessel (*p*) accompanies the nerve (*q*) that is passing backwards to the fourth abdominal segment, behind the first branchia, to which it is distributed after supplying the trunk of the nerve in its course. The other vessels (*u*) are derived from branches of the systemic arteries. TREVIRANUS* long ago described vessels in the Scorpion distributed on the branchiæ; but he acknowledged, in his description of similar vessels in the Spiders, that he was unable to determine whether they are arterial or venous. He seems to have thought that they carry back the blood to the heart. But this is not the case. They are derived from the great systemic arteries, along with which I have traced them upwards to their origin in each chamber. These then are the structures of the pulmonary organs in the Scorpions, a system as perfect as in any of the Articulata, and which will lead us clearly to understand the course of the circulation in these animals.

Course of the Circulation.—The blood received by the veins from the branchiæ is conveyed to the heart round the sides of the segments receiving accessions from other vessels in the segments in its course, and enters the heart at the posterior part of each chamber on its dorsal surface through the orifices of STRAUS. The auriculo-ventricular cavity, dilated by the influx of blood, begins first to contract by the action of the circular fibres at the posterior part of each chamber. By this contraction part of the blood is at once propelled laterally through the systemic arteries to the interior and sides of the body; while the remaining and chief portion is forced onwards through the valves and body of the chamber by the successive contraction of the circular fibres into the next chamber. A fresh accession of blood enters the heart at the auricular orifices in the short interval of time that elapses between the contractile actions of the two chambers, which interval is probably occasioned by the reaction of the lateral muscular appendages of the organ. These contractions, commencing in the principal chamber in the sixth abdominal segment, are carried gradually onwards through the whole of the succeeding segments; so that ere a third chamber has contracted the first is again filled and ready to be emptied, thus occasioning by their alternate movements those pulsatory motions observed in all instances in which the heart is formed of a longitudinal series of chambers and valves, motions which are

* Vermischte Schriften, Anatomischen und Physiologischen Inhalts, vol. i. Gottingen, 1816.

so well known in insects. The blood, propelled by these successive contractions through the aorta, is distributed to the organs in the head and thorax, and the organs of locomotion. Part of it also is sent round the *aortic arches*, through the supra-spinal artery, backwards into the abdomen, giving off its minute currents for the nourishment of the cord, while another portion intermingled with that collected in the portal vessels is sent to the branchiæ. But its principal current still flows in the spinal artery, along the upper surface of the cord to the terminal ganglion of the tail, where it is divided into four streams, two of which go out at the sides of the ganglion to nourish the segment, while the other two, now greatly reduced in size, proceed backwards along the terminal nerves of the cord, and becoming more and more sub-divided in the last segment of the tail are diffused through the surrounding structures. These form minute anastomoses with numerous small vessels, which, gradually collecting in separate trunks on the under surface of the last segment, form the origin of the caudal portion of the subspinal vessel, which conveys the returning blood forwards from the tail to the abdomen to be aerated in the branchiæ before it is again transmitted to the heart. In like manner the blood that has already circulated through the organs of locomotion, the cephalothorax and abdomen, appears to be collected in the *venæ cavæ* which transmit it to the branchiæ before it is again employed in the circulation. Throughout the whole of its course along the artery in the tail the blood is passed in small currents, both anterior and posterior to each ganglion, into the subspinal vessel; thus intermingling the venous and arterial blood precisely as occurs in the abdomen. But the circulation in the caudal prolongation of the heart yet remains to be explained. We have already seen that the great dorsal artery in the tail, above the colon, forms direct vascular anastomoses around its sides with the subspinal vessel on the ventral surface, in which the course of the blood is *forwards* to the abdomen. It is certain, therefore, that the action of the great chamber of the heart must impel the blood at once in every direction, chiefly forwards and laterally, but also in part *backwards* through the caudal artery, otherwise it would be impossible for this structure to form its anastomoses with the subspinal vein without occasioning two opposing currents in the same vessel, and this diversion of the current may perhaps be effected through the interposition of the two imperfect chambers of the heart in the last abdominal segment.

Recapitulation and Conclusion.

Although I propose to continue these investigations of the anatomy and development of the nervous and circulatory systems in the other classes of Articulata, it may be well briefly to recapitulate the principal statements contained in this paper.

1. First, in regard to the nervous system, which has already so deeply engaged the attention of physiologists, certain facts appear, nevertheless, to have been overlooked or imperfectly examined. The double nervous cord is composed in all the Articulata of a superior and inferior series of longitudinal fibres, superimposed one on the other,

as I formerly had the honour of stating to the Royal Society. Both these series may be traced along the whole cord upwards to the cerebral ganglia, and hence may fairly be inferred to minister to volition and sensation, either separately, or, as there seems reason to believe, conjointly, through a mutual, partial interchange of fibres; although it appears almost impossible to demonstrate, with certainty, by any experiment on these structures, the precise individual function of either series. The inferior series is swelled out in each half of the cord, in every segment, into ganglia, from which nervous trunks are given off; while the superior series passes longitudinally over the ganglia, without becoming perceptibly enlarged, or entering into the composition of these ganglia. These enlargements of the cord are produced, in part, by a slight enlargement of the longitudinal fibres themselves, and in part also by the interposition between them of nucleated cells, which are chiefly collected in the middle portion of each ganglion. The ganglia are traversed transversely by fasciculi of commissural fibres, which form part of each nerve given off from the ganglia, as shown by Dr. Carpenter, myself, and others. Those fasciculi of fibres which pass through the ganglia are equal in number to the nerves given off from them, and enter into corresponding nerves on either side. They form no direct connexion with the brain, nor with any nerves anterior or posterior to them in the cord, but only with the corresponding nerves on the opposite side of the ganglia. Their function may therefore be regarded as *commissural* and *reflex*; combining in action the two opposite sides of that segment of the body to which they are distributed. But there are other fibres that form part of the sides of the cord which combine distant parts and segments on the same side, and which, although extending longitudinally in the cord, in part of their course, have no direct connexion with the brain, nor are traceable to that organ. Hence the function of these also, which have not before been pointed out by anatomists, must be regarded as *reflex*, and as combining distant organs or segments on the same side of the body, as the commissural fibres do parts on the opposite side in the same segment. These fibres form the exterior of the nerves and cord. Tracing them from their peripheral extremities, on the surface of the body, they pass inwards to the spinal cord in the course of the nerves, bounding the posterior surface of the root of each as it comes from the ganglion. They are then reflected backwards, and form the postero-lateral surface of the cord, into the composition of which they enter, and along which they are extended backwards until they arrive at the ganglion. They then again pass outwards on the ganglion, forming its antero-lateral surface, to the root of a nerve, along the anterior of which they pass to their peripheral distribution on the surface of the body. Some of these fibres, after joining the cord, seem to pass beyond the next ganglion to be given to nerves from one more distant, so as to form, as it were, a series of circles one within the other. These fibres are joined with all the nerves of the body, both those which pass directly from the ganglia, and those which seem to come from the upper or aganglionic portion of the cord. Now since these fibres have no direct communication with the brain, as may

be shown from the manner in which they bound the posterior roots of the nerves, their influence can only be regarded as reflex, and not as voluntary or sensitive. Consequently, they tend to explain the cause of movements of parts on the same side of the body, excited by irritation of the nervous fibres connected with those parts in distant segments, in accordance with the theory of the reflex movements, as promulgated by Dr. Marshall Hall. The uniform size of the nervous cord, into the structure of which these fibres enter, in the interspaces between the ganglia, is a further reason for inferring their separate existence from those of the longitudinal series, which are traceable to the brain; although they exhibit no structural differences from those series, and their separate existence is not distinctly marked, excepting where they bound the posterior surface of each nerve and ganglion, while passing inwards to form part of the cord. In other respects they closely resemble the fibres of the inferior longitudinal series, to which they are approximated. It is on account of the separate additions of these fibres to the cord, in the interspaces between the ganglia, that I have designated them *fibres of reinforcement of the cord.* According to these views, each nerve is formed of *four sets* of fibres, two of which, derived from the primary structures of the cord, the ganglionic and the aganglionic, which are traceable to the brain, are supposed to minister to volition and sensation: the other two, the fibres of reflected action, are the *commissural,* which communicate with those on the opposite side of the body, and those of *reinforcement,* which, independent of the brain, connect distant parts on the same side of the body. The ganglia of the cord are regarded not only as analogous, anatomically, to the enlarged portions of the cord in Vertebrata, but physiologically as centres of reflexion, agreeably to the views of Dr. Carpenter; and they also possess a still more important character and function in the nervous system, that of being the centres of growth and nutrition to the cord and nerves, the nuclei contained in them being perhaps the sources of supply and nourishment. This is shown from the fact that, in these parts, the fibres of the cord are softer and larger than in the rest of their course; and are elongated during the growth of the body, and the development of new segments; as is seen in the *Polydesmidæ* and *Geophilidæ,* families from the two divisions of Myriapoda. These additional facts fully accord with the already ascertained mode of development *by extension,* or simple growth of the segments.

2. The examination of the circulatory system has afforded many facts, which appear equally new and important. In the whole of the Myriapoda and Arachnida a distinct circulation of the blood is carried on in vessels; and such also is the case in insects and other Articulata. These structures are less perfect in the earliest condition or larva state of the animal in each of these classes, in which many of the structures are still in the course of formation, more especially in those species which undergo a true metamorphosis, as in insects. A distinct system of arterial and venous structures exists in the Myriapoda and Arachnida. The first of these are in the original course of the fluids from the central organ, in the formation of the embryo. The *systemic*

arteries are now first pointed out in the Myriapoda, and their analogues shown in vessels, which heretofore have been imperfectly traced by TREVIRANUS in the Arachnida. The course of the blood to the heart has hitherto been regarded as simply intercellular; but the conclusion now arrived at, from a careful examination, is, that in the perfect state of the animal the blood always flows in vessels, the parietes of which are usually quite distinct, although in some parts of their course they have rather the character of sinuses. These vessels empty themselves at the valvular orifices of STRAUS, with which they appear to be in direct communication, and surround the orifices as delicate membranous structures. They convey back the blood from the branchiæ in the Arachnida around the sides of the body, and are joined by other vessels in their course, and form numerous connexions with the adipose tissues; so that some intermixture of venous and of recently aerated blood from the branchiæ takes place in the course of the fluids to the heart.

The *structure* of the heart and vessels is particularly examined in the Myriapoda and Arachnida, and the vascular collar in each, formed by the *aortic arches*, at the anterior extremity of the aorta, is shown to be a modified condition of the systemic arteries. The distribution of vessels from these arches, both in the Myriapoda and Arachnida, is minutely traced, and the analogies pointed out between the seemingly confused and aggregated distribution in the Arachnida, with corresponding portions of the same structures in the more distinctly developed parts in the Myriapoda. This identification of parts of an intricate distribution of vessels in one animal, and their comparison with those well ascertained in another, exemplifies the uniformity of plan of creation, and the utility of comparative examinations of structure, even in the lowest forms of animals. The course of the *supra-spinal artery*, formed by union of the aortic arches around the œsophagus, is followed into the abdomen, to the extremity of the body in the Myriapoda, and to that of the caudal region in the Scorpion: and the distribution of its branches in these classes is traced outwards along the course of the nerves from the ganglia. Branches from the systemic arteries are traced to their ramifications on the coats of the hepatic vessels, in the first of these animals; and others from those of the visceral systemic arteries to the alimentary canal and liver in the latter; facts which I regard as new demonstrations of the existence of circulatory vessels distributed to the internal organs in Articulata.

A set of vessels which I formerly described as portal vessels are also further examined, and are traced to their terminations in extensive anastomoses and web-like capillary distributions on the branchiæ. The *structure* of the *branchiæ*, and the manner in which the blood seems to permeate their delicate laminæ, and is afterwards collected in sinuses at their base, and again returned to vessels that convey it back to the heart, are also investigated; and the vessels specially given for the nourishment of the branchial structures are noticed. The course of the circulation is traced from the heart, through the systemic arteries, laterally, to the sides of the segments; and forwards, through the chambers and the aortic arches into the cephalothorax

and limbs; and backwards, through the spinal artery into the tail; the returning blood being collected by the portal vessels and sent to the branchiæ, from whence it is again transmitted to the heart. This is the general course of the circulation in the macrourous Arachnida, so that in these there is a current backwards along the great dorsal artery, and the heart propels its fluid in every direction by the successive actions of its chambers.

3. The development of the nervous and circulatory systems is shown to be effected by two modes; first that of growth, *extension*, or enlargement of individual parts; of which mode the elongation of the cord in its gangliated portions is evidence; next, that of *aggregation* of two, or more parts, of the same general structure, to form particular regions, or divisions of that structure. Of this latter mode, to which the term *development* has usually been restricted, the union of two or more originally separate segments of the body, as in the changes of insects, of two chambers of the heart, to form a single chamber, as in the Iulidæ, and the coalescence into one mass of two ganglia and their cords, in which the first mode of development, by simple growth, has been completed, are examples, as in the pseudo-changes of the Myriapoda, and the complete metamorphoses of insects. This latter mode of development usually takes place when the former has been carried to its fullest extent, and is induced by changes in the external structures of the body, being entirely peripheral in its origin. It is not restricted to those animals which undergo a complete metamorphosis, but also takes place, to a greater or less extent, in those in which changes are scarcely perceptible, and in which the first mode of development chiefly prevails. It is also in operation in the first-formed parts of the body, while that of extension is predominant in the latter; as in those beings in which the body is formed of a multitude of similar structures successively produced; as in the Myriapoda, in which it is least predominant in the lowest forms, the Iulidæ, but is carried to its greatest extent in this class in the highest, the *Scutigeridæ*; while in another class, the Arachnida, it has attained its maximum in the earliest conditions of the animal, even before it has escaped from the ovum.

XIII. The Bakerian Lecture.—*An Account of several new Instruments and Processes for determining the Constants of a Voltaic Circuit.* By Charles Wheatstone, *Esq., F.R.S., Professor of Experimental Philosophy in King's College, London, Corresponding Member of the Academy of Sciences at Paris, &c.*

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§ 1.

I INTEND in the present communication to give an account of various instruments and processes which I have devised and employed during several years past for the purpose of investigating the laws of electric currents. The practical object to which my attention has been principally directed, and for which these instruments were originally constructed, was to ascertain the most advantageous conditions for the production of electric effects through circuits of great extent, in order to determine the practicability of communicating signals by means of electric currents to more considerable distances than had hitherto been attempted. In this endeavour, guided by the theory of Ohm and assisted by the instruments I am about to describe, I have completely succeeded. But the use of the new instruments is not limited to this especial object; they will, I trust, be found of great assistance in all inquiries relating to the laws of electric currents, and to the various and daily increasing practical applications of this wonderful agent. An energetic source of light, of heat, of chemical action and of mechanical power, we only require to know the conditions under which its various effects may be most economically and energetically manifested, to enable us to determine whether the high expectations formed in many quarters of some of these applications are founded on reasonable hope, or on fallacious conjecture. The theory we now possess is amply sufficient to direct us rightly in this inquiry, but experiments have not yet been sufficiently multiplied to enable us to obtain, except in a few cases, the numerical values of the constants which enter into various voltaic circuits; and without this knowledge we can arrive at no accurate conclusions.

§ 2.

The instruments and processes I am about to describe being all founded on the principles established by Ohm in his theory of the voltaic circuit, and this beautiful and comprehensive theory being not yet generally understood and admitted, even by many persons engaged in original research, I could scarcely hope to make my descriptions and explanations understood without prefacing them with a short account

of the principal results which have been deduced from it. It will soon be perceived how the clear ideas of electro-motive forces and resistances, substituted for the vague notions of intensity and quantity which have been so long prevalent, enable us to give satisfactory explanations of most important phenomena, the laws of which have hitherto been involved in obscurity and doubt. Viewing the laws of the electric circuit from the point at which the labours of OHM has placed us, there is scarcely any branch of experimental science in which so many and such various phenomena are expressed by formulæ of such simplicity and generality; in most of the physical sciences the facts of observation and experiment have kept pace with theoretical generalization, in this science alone they had gone on accumulating in prolific abundance without any successful attempt having been made to reduce them to mathematical expression. But this is now happily effected, and what has hitherto been mere matter of speculative conjecture is removed into the domain of positive philosophy.

By *electro-motive force* is meant the cause which in a closed circuit originates an electric current, or in an unclosed one gives rise to an electroscopic tension. By *resistance* is signified the obstacle opposed to the passage of the electric current by the bodies through which it has to pass; it is the inverse of what is usually called their conducting power.

When the activity of any portion of the circuit is increased or diminished, either by a change in the electro-motive force or in the resistance of that portion, the activity of all the other parts of the circuit increases or decreases in a corresponding degree, so that the same quantity of electricity always passes in the same instant of time through every transverse section of the circuit.

The force of the current is directly proportional to the sum of the electro-motive forces which are active in the circuit, and inversely proportional to the total resistance of all its parts, or in other words the force of the current is equal to the sum of the electro-motive forces divided by the sum of the resistances.

Let F denote the force of the current, E the electro-motive forces, and R the resistances: then

$$F = \frac{E}{R}.$$

The length of a copper wire of a given thickness, the resistance of which is equivalent to the sum of the resistances in a circuit, OHM calls its *reduced length*, an expression which it will frequently be found convenient to employ.

If the electro-motive forces and resistances in a circuit are proportionately increased or diminished the force of the current remains the same, or $\frac{E}{R} = \frac{nE}{nR}$. Hence a single voltaic element, or a battery consisting of any number of exactly similar elements, if no additional resistance be interposed in the circuit, produces the same effect. Also a thermo-electric element and a voltaic element will produce the same effect when the greatly inferior electro-motive force of the former is compensated by a corre-

sponding decrease in its resistance; in a thermo-electric arrangement the resistance is in general small, because the circuit is entirely metallic, while in a voltaic element the resistance of the liquid is always considerable.

Any interposed resistance weakens the force of the current, but less so as it is smaller in proportion to the other resistances in the circuit. Hence in two circuits, both producing currents of equal force, when the same resistance is introduced, the strength of the two currents may be weakened in very different proportions. A single voltaic element, $\frac{E}{R}$, and a series consisting of any number of such elements, $\frac{nE}{nR}$, form circuits in which the currents have the same force, but very different results will be obtained according as the added resistance is great or small compared with the original resistances in the circuits; if it be small, the effects of the two circuits will remain sensibly the same; but if it be large, the resistance that weakens to a very great extent the current in the circuit of the single element produces but a trifling diminution in that of the series. This explains the necessity of employing a series to overcome considerable resistances. The same remarks will apply to the comparison of a thermo-electric with a voltaic circuit.

The following is the general formula for the force of the current in a voltaic circuit when completed by a connecting wire; the metallic plates of the voltaic elements being parallel to each other and of equal size:

$$F = \frac{nE}{\frac{nRD}{S} + \frac{rl}{s}}.$$

F is the force of the current, E the electro-motive force of a single element, n the number of elements, R the specific resistance of the liquid, D the thickness of the liquid stratum or distance of the plates, S the section of the plates in contact with the liquid, r the specific resistance of the connecting wire, l its length, s its section.

Expressed in words we have the following laws:—

The electro-motive force of a voltaic circuit varies with the number of the elements, and the nature of the metals and liquids which constitute each element, but is in no degree dependent on the dimensions of any of their parts.

The resistance of each element is directly proportional to the distance of the plates from each other in the liquid, and to the specific resistance of the liquid, and is also inversely proportional to the surface of the plates in contact with the liquid.

The resistance of the connecting wire of the circuit is directly proportional to its length and to its specific resistance, and inversely proportional to its section.

The limits of this communication will not allow me to dwell longer on the consequences of Ohm's theory of the electric circuit; for further developments I must refer to the author's work, 'Die Galvanische Kette mathematisch bearbeitet,' Berlin 1827, a translation of which has appeared in Taylor's Scientific Memoirs, vol. ii.; to his various other memoirs published in Schweigger's 'Jahrbuch der Physik;' and to the

more recent applications of the theory made by Fechner, Lenz, Jacobi, Poggendorff, Pouillet, &c.

There is, however, one class of considerations which it is indispensable I should bring forward, because upon it are founded many of the instruments and processes which I shall have occasion hereafter to mention,—I allude to the laws of the distribution of the electric current in the various parts of a circuit, when a branch conductor is placed to divert a portion of the current from a limited extent thereof.

Let λ be the reduced length of the portion of the circuit from which the current is partially diverted, λ' that of the wire which diverts the current, and L that of the undivided part of the circuit. The force of the current in each of the adjacent conductors, λ and λ', can be shown to be in the inverse ratio of their reduced lengths, and the reduced length of a single wire, which substituted for both would not alter the force of the current, to be $\frac{\lambda\lambda'}{\lambda+\lambda'}$, which we will designate by Λ.

The force of the current in the original circuit before the introduction of the branch wire will then be expressed thus:

$$F = \frac{E}{L+\lambda},$$

and the strength of the current in the three different portions of the altered circuit by the following expressions:—

In the principal or undivided portion L,

$$F_1 = \frac{E}{L+\Lambda} = \frac{E(\lambda+\lambda')}{L(\lambda+\lambda')+\lambda\lambda'}.$$

In the portion from which the current has been partially diverted, or λ,

$$F_2 = \frac{E}{L+\Lambda}\cdot\frac{\Lambda}{\lambda} = \frac{E\lambda'}{L(\lambda+\lambda')+\lambda\lambda'}.$$

In the portion which partially diverts the current, or λ',

$$F_3 = \frac{E}{L+\Lambda}\cdot\frac{\Lambda}{\lambda'} = \frac{E\lambda}{L(\lambda+\lambda')+\lambda\lambda'}.$$

§ 3.

It is seldom that any real advance is made in a scientific theory without a corresponding change in its terminology being required. Now that it is proved beyond doubt that the various sources of continued electric action differ from each other only in the amount of their electro-motive forces, modified by the resistance of the circuit of which they form part, it becomes of importance, in order to give precision to our statements and to avoid circumlocutions otherwise inevitable, to adopt general terms to express the source of a current without reference to the peculiar mode of its production; I shall therefore employ the word *Rheomotor* to denote any apparatus which originates an electric current, whether it be a voltaic element or a voltaic battery, a thermo-electric element or a thermo-electric battery, or any other source

whatever of an electric current; when speaking of a single element I shall term it a rheomotive element, and what is usually called a voltaic or thermo-electric pile or battery I shall term a rheomotive series. I shall still use the ordinary expressions when I have to refer to the specific sources of the production of electric currents, but when I employ the general terms they must be understood to apply to all these sources indifferently.

The want of a general term to designate an instrument to measure the force of an electric current without reference to its particular construction has been long felt. I shall use the word *Rheometer* for this purpose, continuing occasionally to employ galvanometer, voltameter, &c. to distinguish the particular instruments to which these names have been applied, though perhaps the terms Magnetic, Chemical, Calorific, &c. Rheometer would be more appropriate.

This may be the proper place to explain a few other terms which I have frequent occasion to use, though not in the course of the present communication. By *Rheotome* is meant an instrument which periodically interrupts a current, and by *Rheotrope* an instrument which alternately inverts it. A *Rheoscope* is an instrument for ascertaining merely the existence of an electric current. The word *Rheostat* will be hereafter explained.

I have not introduced these terms, which will be found greatly convenient and will enable us to state general propositions much more clearly, without good authority. The word Rheophore was employed by AMPÈRE to designate the connecting wire of a voltaic apparatus, as being the carrier or transmitter of the current; and the word Rheometer, first proposed by PECLET as a synonym for galvanometer, has been generally adopted by the French writers on physics.

§ 4.

The method of obtaining the constants of a rheophoric circuit adopted by FECHNER, LENZ, POUILLET, &c., in their experimental verifications of OHM's theory, is essentially the following:—

The resistance of a circuit is determined by observing the force of the current, first without any extra interposed resistance in the circuit, and afterwards when a known resistance is added. Then

$$F = \frac{E}{R}, \text{ and } F' = \frac{E}{R+r} \therefore \frac{F}{F'} = \frac{R+r}{R},$$

from which equation the value of R, all the others being known quantities, is easily deduced. $R = \frac{F'}{F - F'} r$. The electro-motive force of a circuit is ascertained by multiplying the force of the current into the total resistance; for since $F = \frac{E}{R} \therefore E = F R$.

The principle of this method is extremely simple, but the difficulty of determining immediately the force of a current by means of a galvanometer is an obstacle to its

general employment. FECHNER* measured the force of the current by the number of oscillations of the needle when placed at right angles to the coils, a very tedious operation; and others have employed the deviations of the needle, the corresponding degrees of force having been previously determined by some peculiar process, or inferred from some rule depending on the particular construction of the instrument. Another impediment to the use of a galvanometer to measure the force of a current arises from the changes in the magnetic intensity of the needle which frequently occur, especially when it has been acted upon by too strong a current.

The principle of my method is that of employing variable instead of constant resistances, bringing thereby the currents in the circuits compared to equality, and inferring from the amount of the resistance measured out between two deviations of the needle, the electro-motive forces and resistances of the circuit according to the particular conditions of the experiment. This method requires no knowledge of the forces corresponding to different deviations of the needle.

To apply this principle it is requisite to have a means of varying the interposed resistance so that it may be gradually changed within any required limits. I have contrived two instruments for effecting this purpose, one intended for circuits in which the resistance is considerable, the other for circuits where the resistance is small†.

* Massbestimmungen über die Galvanische Kette. Leipzig, 1831, p. 5.

† It appears that the idea of constructing an instrument of this kind had also occurred to Professor JACOBI of St. Petersburgh. When I explained to this eminent experimentalist my instruments and processes in the beginning of August 1840, he informed me that he had himself constructed a similar instrument which he had exhibited to the Academy of Sciences at St. Petersburgh, though no description of it had yet been published, and he at the same time showed me a drawing of it. This instrument, which he has since called an Agometer, differs in mechanical construction from either of mine, and is less convenient to manipulate; but its principle is the same. In a communication which Professor JACOBI made in the following month to the Meeting of the British Association at Glasgow, and which was published in the Athenæum of No. 678, 1840, he thus alludes to the subject:—

"Before proceeding, I may be permitted to make some remarks concerning an instrument which I laid before the Academy of Sciences in the commencement of this year. It is destined to regulate the galvanic current, and is of value in many investigations of this kind. During my sojourn in London, Professor WHEATSTONE has shown me an instrument, founded exactly on the same principles as mine, and with very insignificant modifications and differences. Now, it is quite impossible that he should have had the least notice of my instrument; but as it is probable that its use may be greatly extended, I must add, that while I have only used this instrument for regulating the force of the currents, he has founded upon it a new method of measuring these currents, and of determining the different elements or constants which enter into the analytical expressions, and on which depends the action of any galvanic combination. It is principally to the measure of the electromotive force, by those means, that Mr. WHEATSTONE has directed his attention; and he has shown me, in his unpublished papers, very valuable results which he has obtained by this method."

Professor JACOBI has since his return employed my method of determining the constants of a voltaic circuit. The memoirs in which his results were given were republished in Poggendorff's 'Annalen der Physik,' vol. liv. No. 2. for 1841, and vol. lxii. No. 9. for 1842. To the latter the learned editor, who has made most valuable researches himself in the same path, has appended (p. 89) the following note:—"I will take this opportunity to call to mind that I applied the same method (or at least one identical to it in principle) before it was com-

Fig. 1.

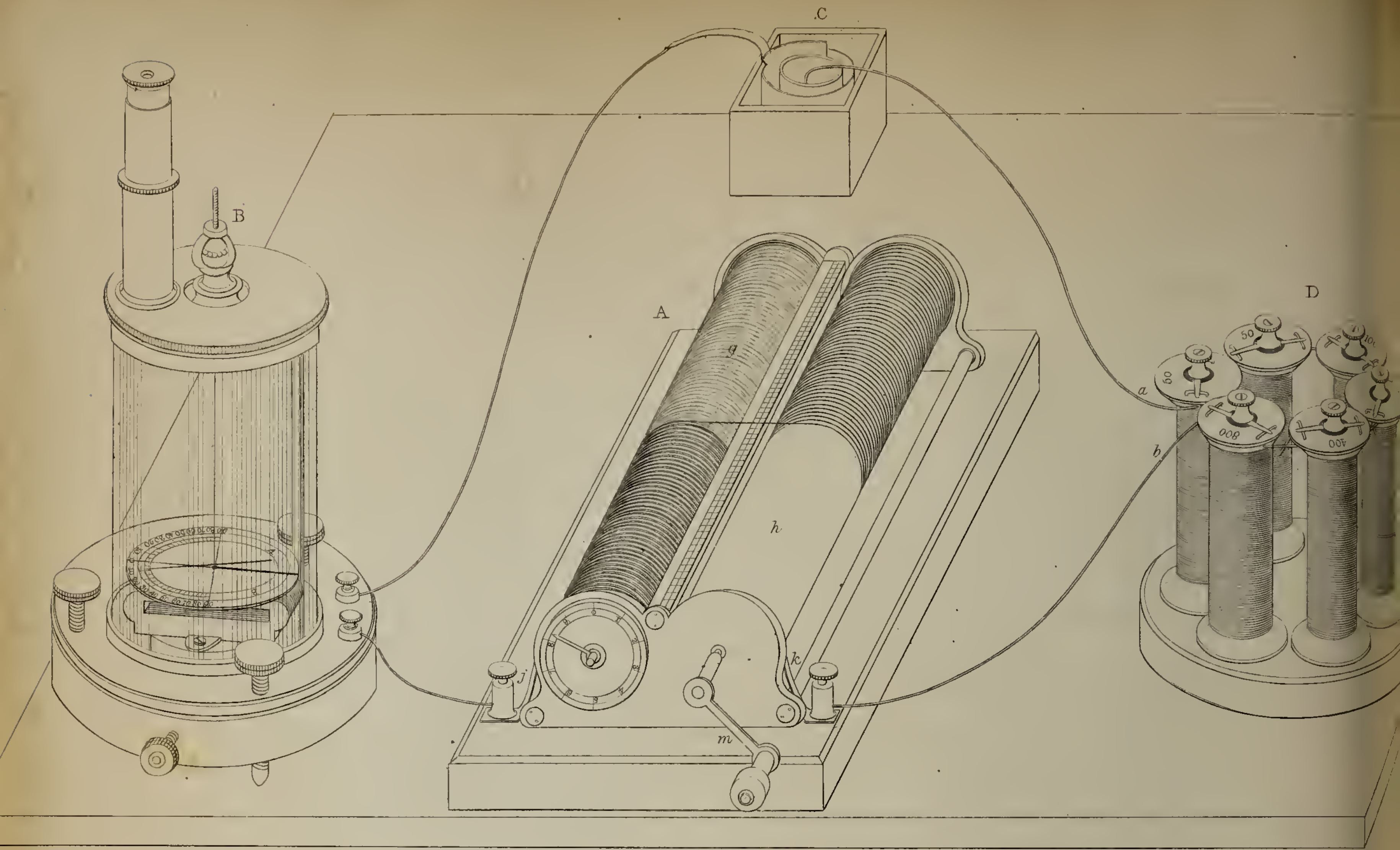
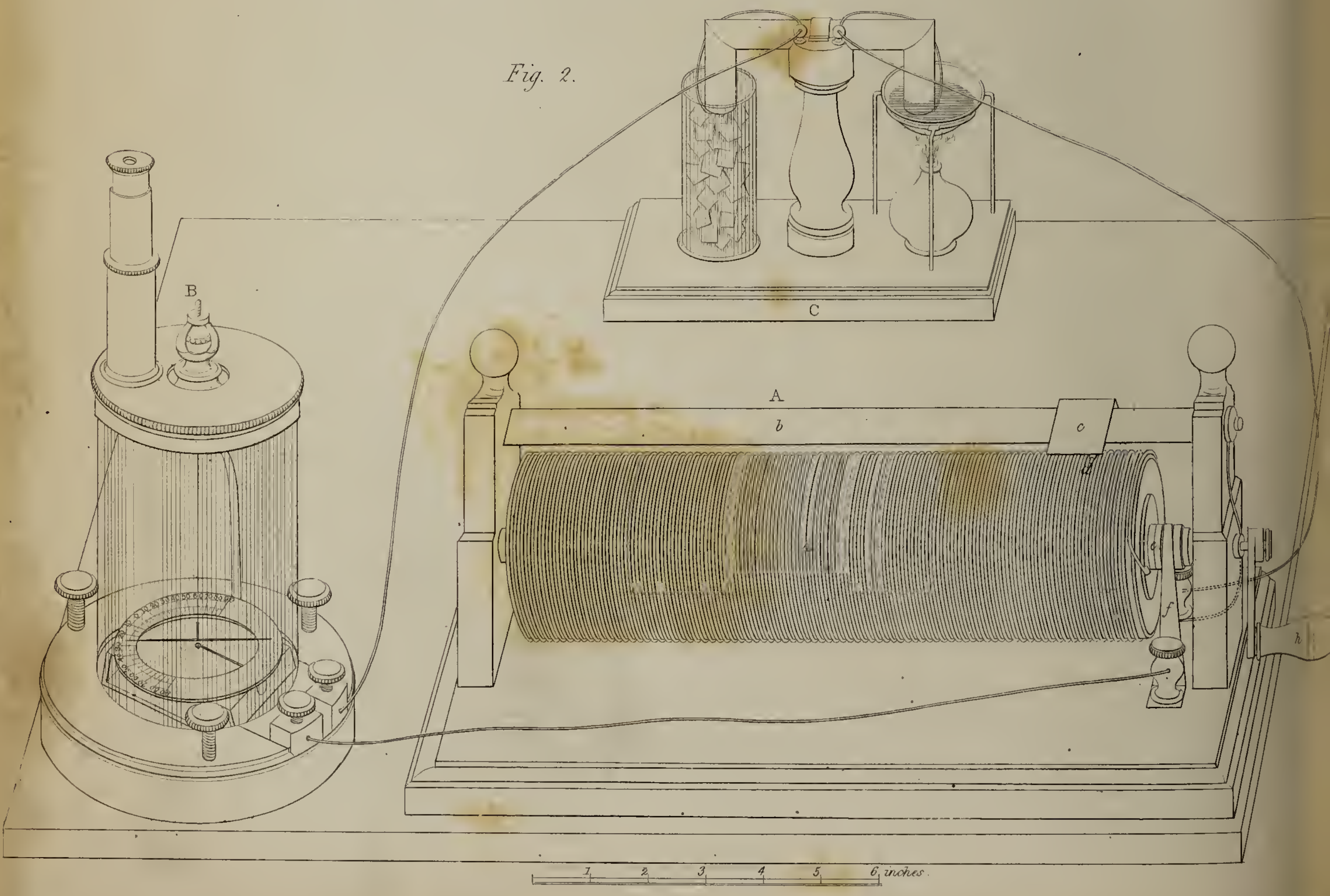


Fig. 2.



§ 5.

The first instrument is represented in Plate XVI. fig. 1. A. *g* is a cylinder of wood, and *h* is a cylinder of brass, both of the same diameter, and having their axes parallel to each other. On the wood cylinder a spiral groove is cut, and at one of its extremities a brass ring is fixed, to which is attached one of the ends of a long wire of very small diameter, which when coiled round the wood cylinder fills the entire groove, and is fixed at its other end to the remote extremity of the brass cylinder. Two springs, *j* and *k*, pressing one against the brass ring on the wood cylinder, and the other against the extremity of the brass cylinder *h*, are connected with two binding screws for the purpose of receiving the wires of the circuit. The moveable handle *m* is for turning the cylinders on their axes. When it is placed on the cylinder *h* and is turned to the right, the wire is uncoiled from the wood cylinder and coiled on the brass cylinder, but when it is applied to the cylinder *g* and is turned to the left, the reverse is effected. The coils on the wood cylinder being insulated and kept separate from each other by the groove, the current passes through the entire length of wire coiled upon that cylinder, but the coils on the brass cylinder not being insulated the current passes immediately from the point of the wire which is in contact with the cylinder to the spring *k*. The effective part of the length of the wire is therefore the variable portion which is on the wood cylinder.

In the instrument I usually employ the cylinders are six inches in length and $1\frac{1}{2}$ inch diameter, the threads of the screw are forty to the inch, and the wire is of brass the $\frac{1}{100}$th of an inch in diameter. I employ a very thin wire and a badly conducting metal, in order that I may introduce a greater resistance into the circuit.

A scale is placed to measure the number of coils unwound; and the fractions of a coil are determined by an index which is fixed to the axis of one of the cylinders and points to the divisions of a graduated circle.

As the principal use of this instrument is to adjust or regulate the circuit so that any constant degree of force may be obtained, I have called it a *Rheostat*.

Plate XVI. fig. 1 shows the arrangement of the circuit when prepared for an experiment. B is a delicate galvanometer with an astatic needle furnished with a microscope for reading off the divisions of the circle, which greatly facilitates the observations. C is the rheomotor.

I must here digress for a moment to describe the voltaic element which I have employed in most of my rheometric researches, and which I have found to be very

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municated to the author by Mr. Wheatstone. See the Annals, vol. lii. p. 526." I have referred to this volume and find it was published in the latter part of 1841, while my communication to Professor Jacobi was, as above stated, made in August 1840. I may also mention, that the experimental process employed by Professor Poggendorff had no resemblance whatever to mine, and the result he sought was likewise different; the mathematical principle of the method was however in the single case he investigated undoubtedly the same.

constant in its action, and convenient to manipulate with. It is quite unnecessary to use large elements in such investigations, for when considerable resistances are introduced in the circuits, which is most frequently the case, they produce no perceptibly greater effect than smaller ones, and in all cases the measures may be as accurately determined by employing small elements as large ones.

The voltaic element C consists of a glazed porcelain cell, two inches square and one inch and a half high, in the centre of which is placed a small porous cylinder of earthenware or wood, filled with a liquid amalgam of zinc, the space between the two cells being charged with a solution of sulphate of copper; a slip of thin sheet copper bent round, and having one of its edges cut and turned over so that the wire of the circuit may be attached to it, or that it may dip into the amalgam of another similar cell, is placed in the solution. Fig. 3, Plate XVII. represents several such elements combined to form a series. It will be seen that, in principle, this is but a slight modification of Professor Daniell's constant battery, liquid amalgam of zinc being employed, as in Mr. Kemp's first experiment, instead of amalgamated zinc bars or plates, and the acid solution being dispensed with. This arrangement is, besides being very constant in its action, extremely economical and easy to manipulate. Any negative metal may be substituted for copper provided a solution of a salt of that metal be employed as the interposed liquid.

§ 6.

The rheostat which I employ for circuits in which the resistance is comparatively small is represented at fig. 2. A. *a* is a cylinder of well-seasoned wood, on the surface of which a spiral groove is cut; a thick copper wire is wound round the cylinder occupying the groove, forming as it were the thread of a screw. Immediately above the cylinder and parallel with its axis is a triangular metal bar *b*, carrying a rider or slide *c*; to this rider a spring *d* is attached, which constantly presses against the spiral wire, yielding to any slight inequality. One end of the spiral wire is attached to a brass ring *e*, against which a spring *f* presses, which is connected by means of a binding screw to one end of the circuit, the other end of the circuit is held by the binding screw which is in metallic connection with the triangular metal bar. On turning the handle *h* the cylinder is caused to move on its axis in either direction, and the rider *c* guided by the wire moves along the bar, advancing or receding according as the cylinder is moved to the right or to the left; the rider coming in contact with a different point of the spiral wire, a different resistance is introduced into the circuit, consisting of that portion of the wire only which is included between the rider and the end of the wire connected with the spring *f*. The cylinder of the instrument I have constructed is $10\frac{1}{2}$ inches in length, and $3\frac{1}{4}$ inches in diameter; the wire is of copper the 16th of an inch thick, and it makes 108 coils round the cylinder. The dimensions of the instrument, and the thickness, length, and material of the wire, may be varied according to the limits of the variable resistance required

to be introduced into the circuit, and the degree of accuracy with which these changes are required to be measured.

Fig. 2 represents the arrangement of a thermo-electric circuit in which this instrument is interposed. C is the thermo-electric element; B the galvanometer, which in this case must not have numerous coils of fine wire as in the preceding arrangement, for this would introduce too great a resistance into the circuit, but must consist of a single thick plate or wire making a single convolution; or, which I think is preferable, the method of diverting a portion of the current from the wire of a delicate galvanometer described in § 15. may be adopted. Any rheomotor in which the resistance is small may be employed in conjunction with this form of the rheostat, instead of a thermo-electric element, as represented.

The rheostat, especially under the form last described, may be usefully employed as a regulator of a voltaic current in order to maintain for any required length of time precisely the same degree of force, or to change it in any desired proportion. Interposed in the circuit of an electro-magnetic engine, however the rheomotor may vary in its energy, the same velocity may be constantly restored by turning the cylinder of the regulator to the left or to the right, according as the velocity increases or decreases; or any different velocity, within given limits, may be obtained by adjusting the rheostat accordingly. Since the consumption of materials in a voltaic battery in which there is no local action decreases in the same proportion as the increase of the resistance in the circuit, this method of altering the velocity has an advantage which no other possesses, the effective force is always strictly proportional to the quantity of materials consumed in producing the power, a point which, if further improvements should ever render the electro-magnetic engine an available source of mechanical power, will be of considerable importance.

In volta-typing operations the advantage of using the rheostat is obvious. By varying the rheostat from time to time so as to keep the needle of a galvanometer to the same point, a current of any required degree of energy may be maintained, without any notable increase or diminution, for any length of time; and, as the nature of the deposit, when the solution from which it is made remains the same, varies only with the force of the current and the magnitude of the surface on which the metal is reduced, when once a good effect has been obtained the same circumstances may be reproduced with ease and certainty, and the effects of chance entirely eliminated.

In the operations of voltatyping, electro-gilding, &c., and in the production of Nobili's colours, the advantage of using the rheostat is obvious.

This however is not the place to dilate on this subject.

§ 7. *Standard of Resistance.*

It is of the highest importance to have a correct standard of resistance, and one that can easily be reproduced for the purpose of comparison. A copper wire of a given length and diameter might be employed, but as very small differences of dia-

meter are attended with considerable differences in the resistances of wires, it is more convenient to assume for the unit of resistance a wire of a given length and weight, which allows small differences to be very accurately determined. I shall in all my experiments, therefore, take for the unit of resistance a copper wire one foot in length, and weighing 100 grains. The diameter of this wire is the ·071 of an inch, and it is intermediate to the numbers designated in commerce as fifteen and sixteen.

§ 8. *The Resistance Coils.*

It is frequently required to measure resistances much greater than can be effected by means of the rheostat, though the reduced length of its wire is considerable. I may wish to know, for instance, the resistance of the wire of the electro-magnets of my telegraphic apparatus, which is sometimes many hundred yards in length; or that afforded by an extensive telegraphic line, or the resistance of a certain extent of an imperfectly conducting liquid. In all these cases and a variety of others I employ another instrument, which enables me to interpose in the circuit resistances to any amount, and yet to obtain by the conjoined use of the rheostat, which serves as its fine adjustment, any required degree of accuracy. This instrument is represented fig. 1. D; it consists of six coils of fine silk-covered copper wire, about the $\frac{1}{200}$th of an inch in diameter; two of these coils are fifty feet in length, the others are respectively 100, 200, 400, and 800 feet in length. The two ends of each coil are attached to short thick wires fixed to the upper faces of the cylinders, which serve to combine all the coils into one continued length; the two wires *a*, *b* form the extremities of the coils by which they are united to the circuit. On the upper face of each cylinder is a double brass spring moveable round a centre, so that its ends may rest at pleasure either on the ends of the thick connecting wires, or may be removed from them and rest only on the wood. In the latter position, the current of the circuit must pass through the coil, but in the former position, the current passes through the spring, and removes the entire resistance of the coil from the circuit. When all the springs rest on the wires, the resistance of the whole series of coils is removed, but by turning the springs so as to introduce different coils into the circuit, any multiple of 50 feet up to 1600 may be brought into it.

As the measurement of these long lengths of wire cannot be accurately depended upon, it is advisable to ascertain the number of units of resistance in each coil, which, with the aid of the rheostat, may be easily effected. I find the resistance of the entire 1600 feet to be equivalent to 218,880 units of resistance, or feet of the standard wire. I occasionally employ an auxiliary series of coils combined in the same way as the preceding, consisting of six coils of the same wire, each 500 yards in length. The reduced length of this series is above 233 miles of the standard wire. By combining it with the preceding, I am able to measure resistances equal to $274\frac{1}{2}$ miles.

§ 9.

When a perfectly constant element, a galvanometer and a rheostat are placed in a circuit as in fig. 1, the resistance of any interposed body may be ascertained in the following way. Observe the point at which the needle stands; then remove the body, the resistance of which is to be measured, from the circuit, and, by means of the rheostat, add a sufficient length of wire to bring the needle again to the same point. The number of standard units corresponding to this added length will be the measure.

It is a point of importance to determine the resistance of the wire of the galvanometer employed in the experiments; to ascertain this by the above method an auxiliary galvanometer would be required, but when a second galvanometer is not at hand, recourse may be had to the following process. Take two rheomotive elements exactly equal both in electro-motive force and resistance; place one of them in the circuit fig. 1, and observe accurately the deviation of the needle; then interpose also the other element and bring the needle again to the same point by means of the rheostat. The equivalent of the wire uncoiled λ, will be the measure of the resistance of the galvanometer wire g plus that of the connecting wires r. Subtracting r from λ, the resistance of g will be determined,

$$\frac{E}{R+r+g}=\frac{2E}{2R+r+g+\lambda} \quad \therefore g=\lambda-r.$$

The resistance of a galvanometer wire or any other interposed resistance may be still more accurately ascertained by means of the instruments described in § 16.

§ 10. *Process to ascertain the Sum of the Electro-motive Forces in a Voltaic Circuit.*

The rheostat affords a most ready means of ascertaining the sum of the electro-motive forces active in a voltaic circuit, without requiring for this purpose the aid of a rheometer graduated to indicate proportional forces, or having recourse to the tedious process of counting the oscillations of a needle, employed by FECHNER in his investigations. To save time and trouble in this operation will be of great importance to the future progress of electro-chemistry, on account of the great number of experiments of this kind which yet remain to be made, and also from the fluctuations in the electro-motive forces of many circuits from chemical and other actions, which render observations requiring considerable time to make completely valueless.

The principle of my process is as follows:—In two circuits, producing equal rheometric effects, the sum of the electro-motive forces divided by the sum of the resistances is a constant quantity, i. e. $\frac{E}{R}=\frac{nE}{nR}$; if E and R be proportionately increased or diminished, F will obviously remain unchanged. Knowing therefore the proportion of the resistances in two circuits producing the same effect, we are able immediately to infer that of the electro-motive forces. But as it is difficult in many cases to

determine the total resistance, consisting of the partial resistances of the rheomotor itself, the galvanometer, the rheostat, &c., I have recourse to the following simple process. Increasing the resistance of the first circuit by a known quantity r, the expression becomes $\frac{E}{R+r}$; in order that the effect in the second circuit shall be rendered equal to this, it is evident that the added resistance must be multiplied by the same factor as that by which the electro-motive forces and original resistances are multiplied, for $\frac{E}{R+r}=\frac{nE}{nR+nr}$. The relations of the lengths of the added resistances r and $n\,r$, which are known immediately, give therefore those of the electro-motive forces.

Experimentally I proceed thus :—I interpose the rheostat and the galvanometer in the circuit, and then add, by means of the former, assisted if necessary by the resistance coils, a sufficient resistance to bring the needle exactly to 45°; I then ascertain the length of wire uncoiled from the brass cylinder of the regulator necessary to reduce the deviation of the needle to 40°. The number of turns is the measure of the electro-motive force, the number corresponding to that of a standard element having been previously determined.

§ 11.

I subjoin a few measures of electro-motive forces obtained by the preceding process.

1. Three elements of different sizes, consisting of copper, a solution of sulphate of copper, and a liquid amalgam of zinc, were successively placed in the circuit. The number of turns of the rheostat requisite to reduce the needle from 45° to 40° were,

Small element described in § 5.	30 turns.
Copper cylinder $3\frac{1}{2}$ inches high and $2\frac{1}{2}$ inches diameter . .	30 turns.
Copper cylinder 6 inches high and $3\frac{1}{2}$ inches in diameter .	30 turns.

Hence, conformably to the theory, the magnitude of an element occasions no difference in its electro-motive force.

2. Five small elements of copper and amalgam of zinc were charged respectively with the following five solutions of copper, the sulphate, the ammonia sulphate, the acetate, the per-muriate and the nitrate. Though the force of the current produced by each element separately was very different, owing to the different conductibility of the solutions, yet, with the exception of the nitrate, all required the same number of turns, indicating equal electro-motive forces; the latter fluctuated between 23 and 29, owing to some disturbing action probably of the nitric acid on the mercury of the amalgam.

3. The electro-motive forces of a circuit in which 1, 2, 3, 4, 5 similar elements were successively placed, were measured.

1 element required	. . . . .	30 turns.
2 elements	. . . .	61 turns.
3 elements	. . . .	91 turns.
4 elements	. . . .	120 turns.
5 elements	. . . .	150 turns.

The electro-motive force of a circuit is therefore, as theory indicates, proportional to the number of similar elements of which it is formed, arranged in series.

4. The next experiments were made to determine the amount of the contrary electro-motive force which is introduced into a circuit when a voltameter or decomposing cell is interposed. The liquid in contact with the platinum electrodes was dilute sulphuric acid. The measure of this contrary electro-motive force is obtained by subtracting the actual number of turns from the number corresponding with the electro-motive force of the circuit when the decomposing cell is removed from it.

		Contrary electro-motive force.
3 elements with decomposing cell	21 turns	90 — 21 = 69
4 elements with decomposing cell	50 turns	120 — 50 = 70
5 elements with decomposing cell	79 turns	150 — 79 = 71
6 elements with decomposing cell	109 turns	180 — 109 = 70
	Mean	70

The contrary electro-motive force may be considered therefore in this case to be constant, and to be to that of a single standard element as 7 : 3. It is hence obvious why three such elements are necessary to decompose water in a cell with platinum electrodes of a certain size, and charged with dilute sulphuric acid. The amount of this contrary force varies with different liquids, and according to the nature of the electrodes employed: as it is not my present object to investigate this subject, but merely to give a few examples of the measures which may be obtained by the above-mentioned method, I shall not enter on the consideration of these interesting but intricate modifications.

5. The highest electro-motive force which a voltaic element consisting of two metals and one interposed liquid can manifest, is when the liquid is a solution of a salt of the negative metal, so that by the continual deposition of this metal the negative surface is kept free from the contact of heterogeneous substances which would tend to give rise to a reverse current. When, in consequence of the chemical action, any heterogeneous solid matter is deposited on, or any evolved gas adheres to, the negative surface, the electro-motive force of the element is reduced. The following measures will show the reduction in electro-motive force of a zinc and copper, and of a zinc and platinum element, by substituting dilute sulphuric acid for the metallic salt; the changes in these cases are effected by the adhesion of hydrogen to the surface of the negative metal.

Amalgam of zinc . .	Sulphate of copper . .	Copper . .	30 turns.
Amalgam of zinc . .	Dilute sulphuric acid .	Copper . .	20 turns.
Amalgam of zinc . .	Chloride of platinum .	Platinum .	40 turns.
Amalgam of zinc . .	Dilute sulphuric acid .	Platinum .	27 turns.

6. The proportion of zinc in the liquid amalgam does not appear to affect the electro-motive force of the voltaic element of which it forms part; the number of turns of the rheostat remains the same although the quantity of zinc may vary very considerably. I was therefore led to think that tolerably accurate measures might be made of the comparative electro-motive forces of the alkaline and earthy bases. An element was formed of liquid amalgam of potassium, sulphate of zinc, and zinc; the potassium was in proportion to the mercury less than 2 per cent.; there was no apparent local action, and the current was remarkably constant and continuous.

The following were ascertained to be the electro-motive forces of different elements in which the positive metal was amalgam of potassium, and the negative metals respectively were zinc, copper and platinum.

Amalgam of potassium . .	Sulphate of zinc . . .	Zinc . . .	29 turns.
Amalgam of potassium . .	Sulphate of copper . .	Copper . .	59 turns.
Amalgam of potassium . .	Chloride of platinum .	Platinum .	69 turns.

The electro-motive force of the first combination nearly corresponds with that of zinc and copper, and when the resistance in the circuit is equivalent, produces a current having nearly the same degree of force. The third combination is one of great electro-motive energy, and when a voltameter with small electrodes is interposed in the circuit, decomposes the water in it abundantly.

It would not be difficult to submit to experiments of this kind all the alkaline and earthy bases; as the proportion in the amalgam does not seem to be of importance, they might be easily prepared by means of a voltaic battery. It would be interesting to know what rank the hypothetical base of ammonia would hold in this scale of electro-motive forces.

7. A still higher electro-motive force may be obtained by employing, in conjunction with the amalgam of potassium, a platinum plate covered with a film of peroxide of lead*. Such a plate is easily prepared by making it the positive electrode in a decomposing cell, charged with a solution of acetate of lead. The films thus formed exhibit, as Nobili has shown, according to their thickness, the colours of Newton's rings.

Amalgam of zinc . .	Dilute sulphuric acid . .	Peroxide of lead .	68 turns.
Amalgam of potassium	Dilute sulphuric acid . .	Peroxide of lead .	98 turns.

* A rheomotive series of ten such elements will have an electro-motive force equal to thirty-three elements of Daniell's battery, or fifty of Wollaston's arrangement in good action. Voltaic combinations, in which peroxide of lead is substituted for the negative metal, have been experimented with by Professors Schönbein (Phil. Mag., 3rd Series, vol. xii. p. 225, March 1838) and De La Rive (Archives de l'Electricité, No. 7, April 1843).

The following measures were obtained when peroxide of manganese was substituted for the peroxide of lead. The peroxide of manganese was deposited on a platinum plate which formed the positive electrode of a decomposing cell containing a solution of chloride of manganese.

Amalgam of zinc . .	Diluted sulphuric acid.	Peroxide of manganese .	54 turns.
Amalgam of potassium	Diluted sulphuric acid.	Peroxide of manganese .	84 turns.

A weak current is produced by employing a clean platinum plate in conjunction with one covered with the peroxide, in which combination the former acts the part of zinc. In this case the positive metal undergoes no chemical action, but on the negative side the peroxide is reduced by the evolved hydrogen.

8. The following measures conclusively show, that if three metals be taken in their electro-motive order, the electro-motive force of a voltaic element, formed of the two extreme metals, is equivalent to the sum of the electro-motive forces of the two elements formed of the adjacent metals.

1.

Amalgam of potassium .	Sulphate of zinc . .	Amalgam of zinc	29 turns.
Amalgam of zinc . . .	Sulphate of copper .	Copper . . .	30 turns.
Amalgam of potassium .	Sulphate of copper .	Copper . . .	59 turns.

2.

Amalgam of potassium .	Sulphate of zinc . .	Amalgam of zinc	29 turns.
Amalgam of zinc . . .	Chloride of platinum	Platinum . . .	40 turns.
Amalgam of potassium .	Chloride of platinum	Platinum . . .	69 turns.

9. I wished to compare the electro-motive force of a thermo-electric element, the two metals of which were bismuth and copper, and whose opposite joints were exposed to the fixed temperatures of 32° and 212°, with that of a standard voltaic element. As the interposition of the galvanometer greatly reduced the force of the current in the thermo-electric circuit, so that I could not advance the needle to 45°, I employed, instead, the reduction of the needle from 10° to 5°. The ratios of the measures of the electro-motive forces remain the same between whatever two points the needle is made to vary, provided they do not change during the same series of experiments.

Thermo-electric element of bismuth and copper, the temperatures of the joints being 32° and 212°	8 turns.
Standard voltaic element of amalgam of zinc, sulphate of copper, and copper	757 turns.

The relative electro-motive forces are therefore as 1 : 94·6*.

* Pouillet, by a very different process, has ascertained this proportion to be as 1 : 95. See Élémens de Physique Expérimentale, 3ième ed. tom. i. p. 631.

§ 12.

The resistance or reduced length of a rheomotor may be ascertained by either of the following processes :—

First Method.—Place the galvanometer and the rheostat in the circuit, and adjust the latter until the needle of the galvanometer stands at a determined point. Then divide the current which passes through the wire of the galvanometer, by placing an equal resistance by its side ; the needle will recede. The reduced length, measured by the number of turns of the rheostat, required to be taken out of the circuit in order to make the needle stand at its former point, will be equal to half the total resistance of the undivided portion of the original circuit. The resistance of the galvanometer and connecting wires, and of the coils of the rheostat in the circuit before the experiment, having previously been determined, that of the rheomotor is easily obtained by subtracting the former from the total resistance measured.

Let E be the electro-motive force, g the resistance of the galvanometer wire, and R all the other resistances in the circuit. The force of the current acting upon the needle will be $F = \frac{E}{R+g}$; adding by the side of the galvanometer wire another wire having the same resistance, is equivalent to substituting for it a wire of double section, and the expression for the resistance of the circuit becomes $R + \frac{g}{2}$; but since, in consequence of the division of the current, only one-half its force acts upon the needle, this action may be represented by $\frac{\frac{1}{2}E}{R+\frac{1}{2}g}$. To render this expression equivalent to the first, the resistance R must be reduced one-half, for $\frac{E}{R+g} = \frac{\frac{1}{2}E}{\frac{1}{2}R+\frac{1}{2}g}$; the resistance taken out of the circuit to effect this reduction is obviously equal to half the resistance of the undivided portion of the original circuit ;

or $$\frac{E}{R+g} = \frac{\frac{1}{2}E}{R+\frac{1}{2}g-\lambda} \qquad \therefore \lambda = \frac{R}{2}.$$

Second Method.—Bring the needle of the galvanometer, by means of the rheostat, to a determined point which we will call b. Ascertain the resistance r requisite to reduce the needle to a lower point a. Restore it to b ; then place a wire to divide the current with the galvanometer, and alter this wire until the needle again stands at a. When the needle stands at b, $F = \frac{E}{R+g}$; when it stands at a in the first case $F' = \frac{E}{R+g+r}$, in the second case $F' = \frac{E\,r'}{R\,(g+r')+g\,r'}$.

Equating these two expressions,

$$\frac{E}{R+g+r} = \frac{E\,r'}{R\,(g+r')+g\,r'}, \qquad \therefore R = \frac{r\,r'}{g},$$

and as these factors are known, R may be readily determined. The resistance of the rheomotor may be obtained from this as before.

If $r' = g$, that is if the resistance of the galvanometer wire be equal to that of the wire which diverts a portion of the current from it, then $R = r$.

Third Method.—Bring the needle to any determined point, and ascertain by means of the instrument described at § 18. what degree corresponds to one-half the intensity thus indicated. Since, when the electro-motive force remains the same, the force of the current is simply inversely as the total resistance, to reduce the needle from a to $\frac{a}{2}$ a resistance exactly equal to that previously existing in the circuit must be added; therefore the number of turns of the rheostat required to reduce the needle from a to $\frac{a}{2}$ will be the measure of the total resistance of the circuit when the needle stood at a. The total resistance being thus measured, that of the rheomotor is determined by subtracting from it the other known resistances, including that of the galvanometer.

More generally, if the forces of two currents, a and b, corresponding to two stationary positions of the needle, are known (§ 19.), the total resistance of the circuit will be $R = \frac{b\,r}{a - b}$, r being the resistance added to reduce the current from a to b. If $a = 2\,b$, then $R = r$ as before.

Fourth Method.—For this and the following process two exactly equal rheomotors must be employed; their equality may be tested by successively interposing them in the same circuit, when one and the other should deflect the needle of the galvanometer precisely to the same degree.

Place one rheomotor in the circuit and adjust the rheostat until the needle points to any degree arbitrarily fixed upon; then add the second element by the side of the first, and increase the reduced length of the circuit by turning the rheostat until the needle again points to the same division. The known quantity, measured by the number of turns of the rheostat, by which the reduced length of the circuit is increased, is equal to one-half the resistance of a single rheomotor. By placing the second rheomotor by the side of the first, the resistance of that portion of the circuit is reduced one-half; therefore, to restore the former condition of the circuit, a resistance equal to one-half that of the rheomotor must be added. For

$$\frac{E}{R + r} = \frac{E}{\frac{R}{2} + r + \lambda} \qquad \therefore \lambda = \frac{R}{2},$$

R being the resistance of the rheomotor, and r the other resistances in the first circuit.

Fifth Method.—Place both the rheomotors in series, and vary the resistance until the needle stands at any determined degree. Then place them side by side, and increase the resistance, by turning the rheostat until the needle again stands as before. The resistance of a single rheomotor is equal to twice the resistance required to be added, plus all the resistances in the first circuit except that of the rheomotor,

$$\frac{2\,E}{2\,R + r} = \frac{E}{\frac{R}{2} + r + \lambda} \qquad \therefore R = r + 2\,\lambda,$$

R being the resistance of the rheomotor, r the other resistances in the first circuit, and λ the resistance added by the rheostat to make the force of the current in the second circuit equal to that in the first.

The resistance of one of the elements of the battery described in § 5, I have found to be equal to 2128 standard units.

§ 13.

The resistance of a standard rheomotor having been accurately determined by either of the processes above described, the resistance of any other rheomotor, in which the electro-motive force is the same, may be obtained by a still more expeditious method. The needle of the galvanometer being brought to a determined point when the standard rheomotor is interposed in the circuit; if this be removed, and the rheomotor to be measured be substituted in its place, the number of coils of the rheostat, added to or subtracted from the circuit, to make the current in the latter case equal to that in the former, when added to or subtracted from the resistance of the standard rheomotor, will give that of the rheomotor to be measured. If R' be greater than R, $R' = R + r$; but if R' be less than R, $R' = R - r$. By this simple process the resistances of voltaic elements of different forms, magnitudes, &c. may be readily compared.

§ 14. *Instrument for Measuring the Resistance of Liquids.*

We do not at present possess any accurate measures of the conductibilities of liquids, nor have there yet been formed any tables which show the even real order of their conducting powers. In the experiments having this object in view which have hitherto been made, the contrary electro-motive force, which generally arises when the electric current passes through a liquid capable of undergoing decomposition (§ 11,4.), has been left entirely out of consideration, and the results therefore have widely deviated from the truth. By the simple instrument represented at Plate XVII. fig. 4, I have been able to eliminate completely this source of error, and to obtain perfectly constant results. A is a glass tube about two inches long and half an inch in internal diameter; a portion of the tube is ground away for an inch and a quarter of its length, so as to leave a segment of 270°; at one extremity of this aperture is fixed a metal plug terminated by a platinum plate, and at the other end is a moveable piston, terminated also by a plate of platinum, capable of being advanced to within a quarter of an inch from the fixed plate; the range of its motion is thus limited to one inch, and an attached micrometric apparatus enables any portion of this distance to be accurately measured. To obtain the measure of the resistance of a liquid I proceed in the following way:—I interpose in the circuit a small constant battery, consisting of about three elements, with the rheostat, the resistance-coils, the galvanometer, and the measuring tube just described. The end of the piston being a quarter of an inch distant from the fixed plate, I fill the intervening space with the liquid, the resistance

Fig. 5.

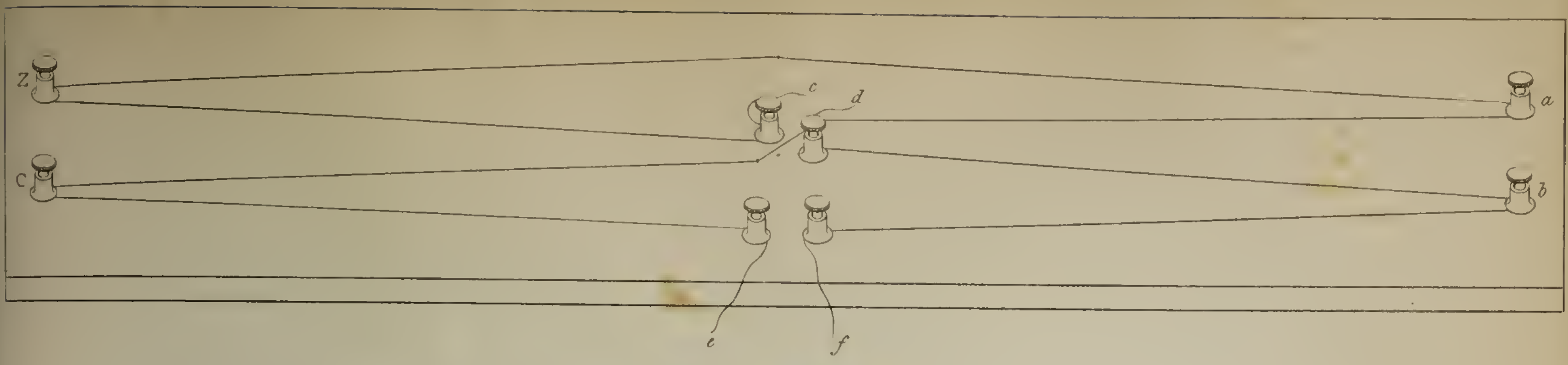


Fig. 8.

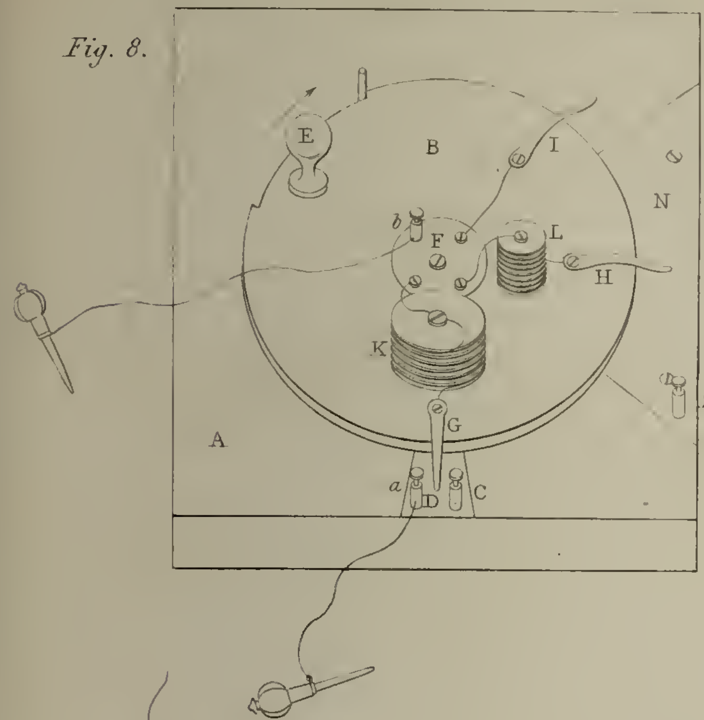


Fig. 7.

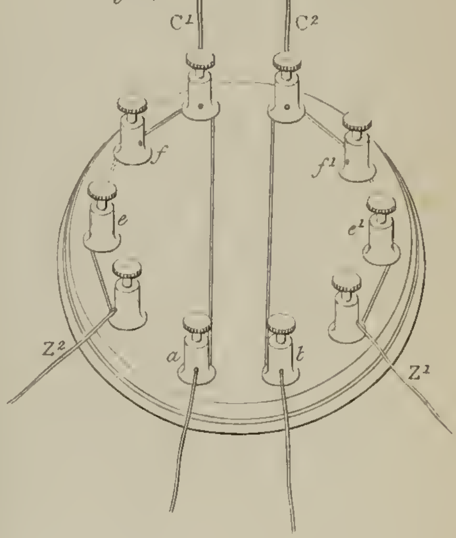


Fig. 3.

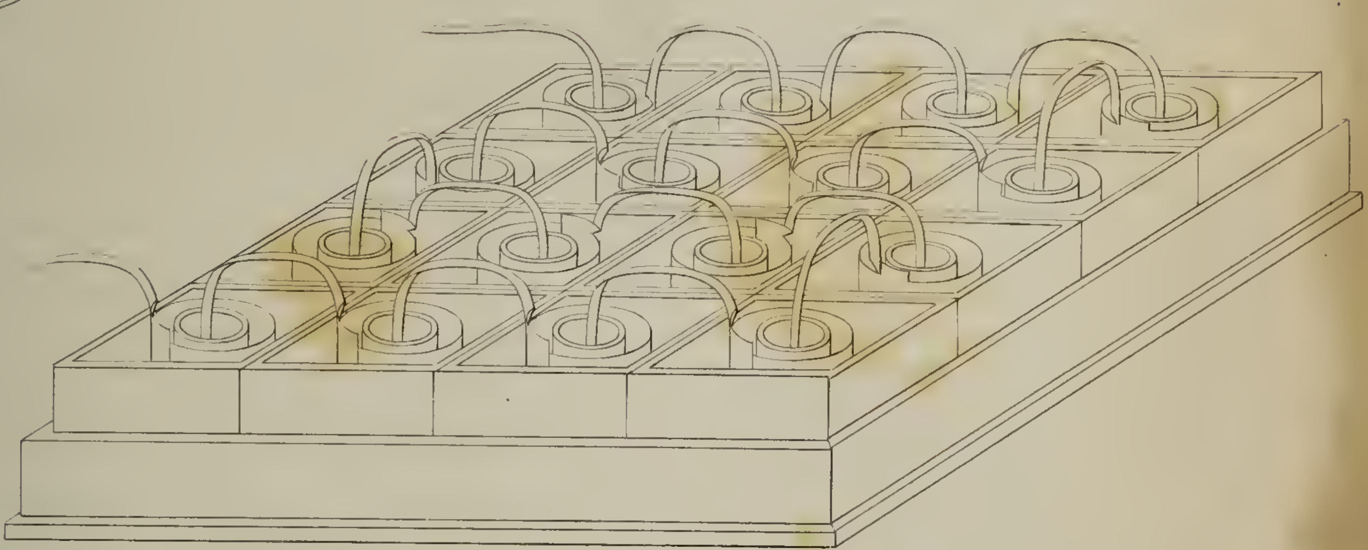


Fig. 4.

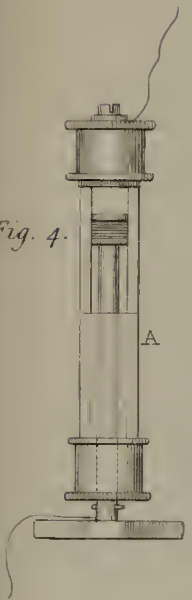
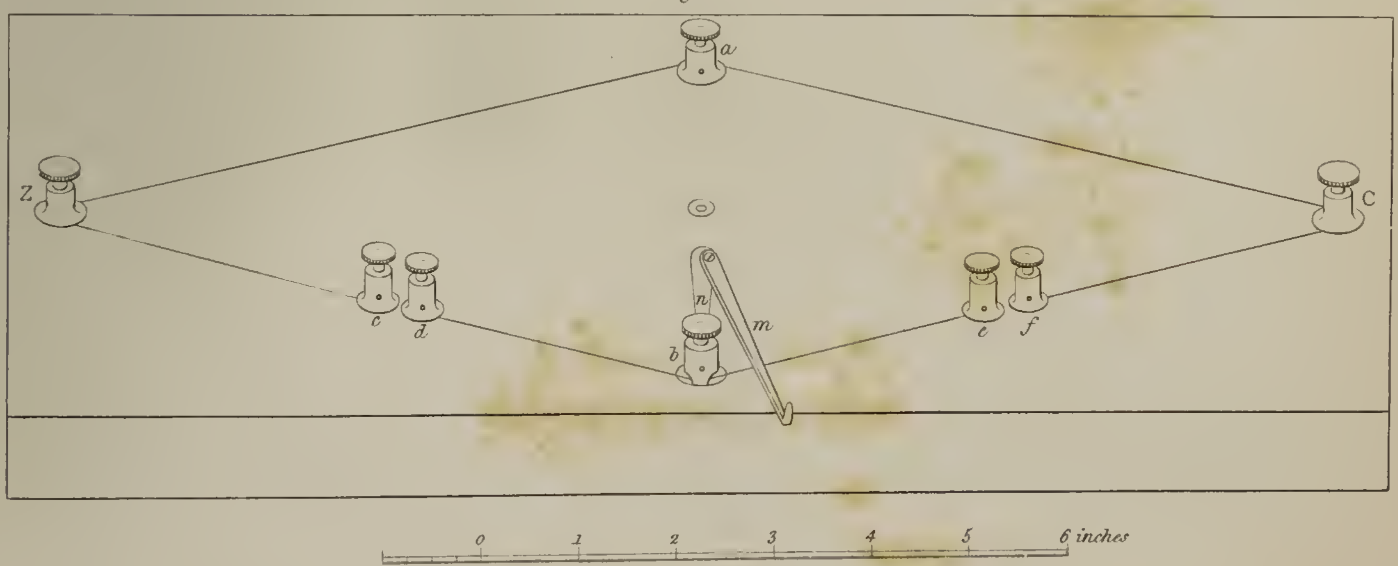


Fig. 6.



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of which is to be measured. I then adjust the rheostat to bring the needle of the galvanometer to a determined point; this having been noted, I draw the piston back through the entire remaining space of one inch, and fill the vacancy with the same liquid; the needle will recede towards zero. I then diminish the resistance of the circuit by means of the rheostat and the resistance-coils, until the needle stands at the same point that it did when only a quarter of an inch of the liquid column was interposed. The reduced length of the wire thus taken out of the circuit will be the measure of the resistance of one inch of the liquid. The contrary electro-motive force arising from the decomposition of the liquid exists in the circuit during the whole process, and therefore does not affect the result.

The measure of the resistance of a liquid must be made immediately after it is placed in the circuit, because if a current be allowed to act upon it for any length of time the nature of the solution changes. In the case of sulphuric acid, for instance, the solution is rendered stronger by the decomposition and consequent diminution of the water, while, in the case of a metallic salt, not only is the water decomposed, but the metal is reduced, and free acid is liberated. Under the conditions, however, of my experiments, the chemical action is so slow, and the time of operation is so short, that no sensible changes of this kind take place.

The resistance of liquids to the transmission of electricity is, no doubt, one of their most important physical properties. An investigation of all the circumstances which occasion changes in this property, especially if accompanied with accurate quantitative determinations, must necessarily lead to important and hitherto unobserved relations. To investigate the changes due to different degrees of dilution and temperature alone will be a task requiring considerable patience. I have made many measures of the specific resistances of different conducting liquids, by the aid of the preceding process, but as they have not been sufficiently numerous to enable any general conclusions to be drawn, and as I am at present engaged in a more extensive series of experiments in which strict attention will be paid to all the known influencing circumstances, I shall defer an account of them to a future occasion.

As bodies differ so much from each other in their specific resistances, and as the means of determining this property are so easy, it cannot be doubted that hereafter this process will be extensively employed to detect the purity of substances and to distinguish them from each other.

Another method of measuring the resistance of a conducting liquid is the following: —Prepare a circuit the electro-motive force and resistance of which is known, $\frac{E}{R} = F$. Interpose the liquid which is to be the subject of experiment in a small cell with two parallel platinum electrodes; the expression for the circuit will then be $\frac{E - e}{R + x} = F'$; e being the contrary electro-motive force, and x the resistance of the liquid which is to be determined. Having ascertained the value of e by the process described in § 10, sub-

tract, by means of the rheostat and coils, a resistance which shall make the force again equal to F; the expression will then become $\frac{E-e}{R+x-\lambda}=\frac{E}{R}$, whence $x=\lambda-\frac{e}{E}R$. Therefore the resistance x of the liquid is equal to the resistance λ taken out of the circuit by the rheostat, minus the total resistance of the original circuit multiplied by the ratio $\frac{e}{E}$.

§ 15.

When a galvanometer is employed to measure the force of a current, its wire is usually interposed in the circuit. But it is impossible, in this way, to make use of the same galvanometer to measure the force of the current in circuits of different kinds. A galvanometer with numerous coils of thin wire adds a very considerable resistance to a circuit in which the electro-motive force is great and the resistance small; while, on the other hand, a galvanometer with a short thick wire will give scarcely any indication in a circuit in which the resistance is very great, though the electro-motive force may be considerable. Besides, a delicate galvanometer is incapable of indicating energetic forces.

But by the following simple means the same delicate galvanometer may be employed to measure forces of every degree of energy, and in all kinds of circuits, without introducing any inconvenient resistance into them.

If the current be caused to pass simultaneously through two paths, one being the wire of the galvanometer, and the other another wire connected with its two ends, the current will be divided in the inverse proportion of the resistances of the two paths. The action upon the needle of the galvanometer may hereby, by employing different wires to divert a portion of the current, be reduced to any degree. If the proportionate forces are known for the galvanometer without the reducing wire, they will remain equally proportionate whatever the resistance of the latter may be; but measures made with the same instrument, with different reducing wires applied, will not be comparable unless the changed resistance of the galvanometer thus modified be taken into account.

But strictly comparable measures may be obtained, if the precaution be taken of adding, to the principal portion of the circuit, a resistance which will compensate for the diminution of resistance occasioned by placing the reducing wire. Let g be the reduced length of the galvanometer wire, and ng that of the reducing wire. The force of the current in the principal portion of the circuit will be to that in the galvanometer wire as $1:\frac{n}{n+1}$. The resistance to be added to the principal portion of the circuit, in order to maintain the current the same as when no reducing wire is added, is $\frac{g}{n+1}$.

When the measures of energetic currents are required to be determined by means of a delicate galvanometer, it is sufficient to attach its two ends to two points of the

conducting wire*. The distance between these points must remain the same in all comparative experiments, but the absolute deviations of the needle will be greater as these points are further from each other. In the case of the circuit of a powerful electro-magnetic engine, or of a volta-typing apparatus, the diminution of resistance occasioned by connecting the galvanometer wire in the manner above described is so trifling that it would be useless to take it into account, and the compensation above alluded to is, therefore, unnecessary.

§ 16. *The Differential Resistance Measurer.*

The method of determining the resistance of metal wires and other conductors of electricity by means of the rheostat, described in § 9, is inapplicable when small differences are to be observed. If, for instance, a short length of wire has to be examined, its resistance is so small compared with the other resistances in the circuit, including that of the battery, that whether it be interposed or not, no change is observable in the deviation of the needle; and, even if greater lengths of the conducting substance be employed, fluctuations in the power of the battery frequently render the observation uncertain.

The differential galvanometer proposed by M. Becquerel, had it been an instrument as practically as it is theoretically perfect, would have enabled us to ascertain very minute differences of resistance with great facility. But it is almost impossible so to arrange the two coils that currents of equal energy circulating through them shall produce equal deviations of the needle in opposite directions, the consequence of which is that the standing of the needle at zero is no indication of equality in the currents. This and other defects have prevented the differential galvanometer from coming into use.

All the advantages, however, which were expected from this instrument may be obtained, without any of its accompanying defects, by means of the simple arrangement I am about to describe, which, moreover, has the advantage of being immediately applicable to any galvanometer, instead of requiring, as in the former case, the instrument to be peculiarly constructed.

Fig. 5 represents a board on which are placed four copper wires, Z *b*, Z *a*, C *a*, C *b*, the extremities of which are fixed to brass binding screws. The binding screws Z, C are for the purpose of receiving wires proceeding from the two poles of a rheomotor, and those marked *a*, *b* are for holding the ends of the wire of a galvanometer. By this arrangement a wire from each pole of the rheomotor proceeds to each end of the gal-

* Professor Petrina of Linz has proposed (Poggendorff's 'Annalen,' vol. lxii. 1842, No. 9) a similar means of measuring and comparing electric currents of every degree of force. He interposes in the circuit a canal of mercury, the section of which is four square lines, and plunges into it, at various distances from each other, the ends of the wire of a sensitive galvanometer. He shows that if the resistance in the galvanometer wire be very considerable, and that of the mercury in the canal be small in comparison, the force acting on the galvanometer needle will be sensibly proportional to the distance between the ends of the wire, and he has founded on this principle a ready approximative method of graduating the galvanometer.

vanometer wire, and if the four wires be of equal length and thickness, and of the same material, perfect equilibrium is established, so that a rheomotor however powerful will not produce the least deviation of the needle of the galvanometer from zero. The circuits Z *b a* C Z, and Z *a b* C Z, are in this case precisely equal, but as both currents tend to pass in opposite directions through the galvanometer, which is a common part of both circuits, no effect is produced on the needle. Currents are however established in Z *b* C Z, and Z *a* C Z, which would exist were the galvanometer entirely removed. But if a resistance be interposed in either of the four wires, the equilibrium of the galvanometer will be disturbed; if the resistance be interposed in Z *b* or C *a*, the current Z *a b* C Z will acquire a preponderance; if it be inserted either in Z *a* or C *b*, the opposite current, Z *b a* C Z, will become the most energetic. If the resistance interposed in the wire be infinite, or which is the same thing, if the wire (which we will suppose to be C *b*) be removed, the energy of the current passing through the galvanometer will be that of a partial current Z *b a* passing through one of the wires plus the galvanometer wire; the path of the diverted portion of the current being Z *a*. According to this disposition, the force of the original current $= \frac{E}{R + 2r + g}$, and that of the partial current acting on the galvanometer $= \frac{Er}{R(3r + g) + 2r^2 + rg}$; R being the resistance of the rheomotor, r that of a single wire, and g that of the galvanometer.

The equilibrium having been disturbed by the introduction of a resistance in one of the wires, it may be restored by placing an equal resistance in either of the adjacent wires. For the purpose of interposing the measuring resistance and the resistance to be measured, the wires Z *b* and C *b* are interrupted, and binding screws, *c*, *d* and *e*, *f*, are fixed for the reception of the ends of the wires. The equilibrium when once established is not in any degree affected by fluctuations in the energy of the rheomotor.

Fig. 6 represents a different and, in some respects, a more convenient arrangement of the wires to produce the same result; the same reference letters are employed, and the preceding observations apply to it equally.

Slight differences in the lengths, and even in the tensions of the wires, are sufficient to disturb the equilibrium; it is therefore necessary to have an adjustment, by means of which, when two exactly equal wires are placed in C *a* and Z *a*, the equilibrium may be perfectly established. For this purpose, in the instrument, fig. 6, a piece of metal *n*, connected with the binding-screw *b*, is inlaid in the board, and another piece of metal *m* moves round *n* as a centre, whilst its free extremity always rests on the wire. According as the moveable piece of metal makes a greater angle with the fixed piece, the resistance of the path Z *b* is diminished; if, however, the equilibrium is disturbed because the resistance in C *b* is too great, the moveable piece of metal must be placed on the opposite side of the fixed piece.

No fixed dimensions can be assigned to these instruments. The boards of those I employ are fourteen inches long and four inches wide, and the wire is copper $\frac{1}{20}$th of an inch in diameter. A single voltaic element of large surface will produce a more considerable effect than a battery of small elements*. A thermo-electric arrangement, or a magneto-electric machine may be substituted for the voltaic element or battery; and a voltameter or any other description of rheometer may in some cases supply the place of the galvanometer. It is scarcely necessary to state that these instruments are not adapted to measure the resistances of substances capable of undergoing chemical changes from the action of an electric current, on account of the contrary electro-motive forces which arise under such circumstances†.

§ 17.

Another differential arrangement, which will be found useful in some circumstances, may be worth mentioning; it is much more sensible than the preceding, but as the equilibrium indicated is that between two currents generated by independent rheomotors, instead of diverted portions of the same current as in the instruments previously described, the state of equilibrium will be disturbed by every fluctuation, whether of the electro-motive force, or resistance of either of the rheomotors; it can therefore only be safely employed when these are perfectly constant, or when the object is not to measure resistances, but to observe the comparative changes in two rheomotors.

Fig. 7 represents a circular board on which are fixed ten binding screws; the wires proceeding from one of the rheomotors are to be attached to C^1 and Z^1, those from the other to C^2, Z^2, and the ends of the galvanometer wire are to be fixed to a and b. The two currents, $C^1\,a\,b\,Z^1$ and $Z^2\,a\,b\,C^2$, tend to pass through the galvanometer wire in opposite directions. When two equal wires are interposed between $e\,f$ and $e'\,f'$, if the opposing currents be equal, perfect equilibrium is established in the galvanometer wire, and the needle remains at zero. But if the force of the current in either of the rheomotors varies, or, if while the force of the two rheomotors remains constant, the slightest difference is occasioned in the resistance of either of the wires interposed between $e\,f$ or $e'\,f'$, the equilibrium in the galvanometer wire is disturbed and the needle is deflected.

* When a single element of Daniell's battery, 6 inches high and $3\frac{1}{2}$ inches diameter, is employed, and two copper wires two feet long and $\frac{1}{40}$th of an inch diameter are interposed in the instrument, an augmentation of the tenth of an inch in one occasions a deviation of 2° in the galvanometer needle. This will suffice to show the accuracy with which resistances may be measured by this instrument.

† Mr. Christie, in his "Experimental determination of the laws of magneto-electric induction" printed in the Philosophical Transactions for 1833, has described a differential arrangement of which the principle is the same as that on which the instruments described in this section have been devised. To Mr. Christie must, therefore, be attributed the first idea of this useful and accurate method of measuring resistances. Another differential arrangement, proposed also in the same memoir, is analogous to that which forms the subject of the following section.

§ 18.

It would greatly facilitate our quantitative investigations if we had a certain and ready means of ascertaining what degree of the galvanometric scale indicated half the intensity corresponding to any other given degree. The properties of diverted currents, established by the theory of OHM, and fully confirmed by experiment, enables me to propose a simple method by which this object may be completely attained.

If a wire of the same length, thickness and conductibility as that of the galvanometer be placed so as to divert a portion of the current from it, it is obvious that one-half of the current will pass through the galvanometer wire, and the other half through the diverting path. Though it simplifies the consideration to suppose the extra wire to have the same length, diameter and conducting power, it is easy to see that the same result follows if the two wires present the same resistance which they do whenever $s' c' l = s c l'$. If the added wire produced no alteration in the intensity of the principal current, one-half of the former force would act upon the galvanometer ; but this is not the case, the addition of the wire produces the same effect as doubling the section of the galvanometer wire would do, and the total resistance of the circuit is therefore diminished. If the strength of the original current when it passes wholly through the galvanometer $= \frac{E}{R+r}$ (r being the resistance of the galvanometer wire, and R all the other resistances in the circuit), $\frac{E}{R+\frac{r}{2}}$ will be the strength of the principal current when the extra wire is added ; if now an additional resistance $= \frac{r}{2}$, that is to say, a wire whose resistance is equal to half that of the galvanometer wire, be added to the principal portion of the circuit, the intensity will be again $\frac{E}{R+\frac{r}{2}+\frac{r}{2}}$, and the force acting on the galvanometer will be exactly half what it was at first.

The construction and use of the instrument (fig. 8) will now be easily understood. A is a square piece of wood, having two insulated pieces of brass, D, N, inlaid on its surface, on which are fixed the binding screws C, Z and a ; B is a circle also of wood, moveable round its centre ; upon this moveable circle are fixed the insulated piece of brass F, with the binding screw b upon it, and three springs G, H, I, the free ends of which press on the board A. A coil of wire K, the equivalent resistance to the wire of the galvanometer, measured by the process described in § 16, is connected by its two ends with the brass plate F and the spring G ; and another coil, L, the resistance of which is one-half that of the former, is similarly interposed between the brass plate and the spring H. A short wire immediately connects the plate F with the spring I. E is a nut or pin by which the moveable circle is moved through a small arc.

The wires proceeding from the poles of a rheomotor being connected with the

binding screws C, Z, and the ends of the galvanometer wire being attached to the screws a and b; in the position of the instrument represented in the figure, the springs G and H resting respectively on the insulated pieces of brass D and N, the principal portion of the current passes through the resistance coil L, and the current is afterwards equally divided between the coil of the galvanometer and the resistance coil K. But when the circle is moved in the direction of the arrow, the springs G, H leave the brass plates, and rest on the wood, while the spring I is brought into contact with the plate E; both of the resistance coils are now thrown out of the circuit, and the current passes wholly through the wire of the galvanometer.

It is almost unnecessary to state that this instrument can only be used in conjunction with the galvanometer to which its resistance coils K and L have been adjusted.

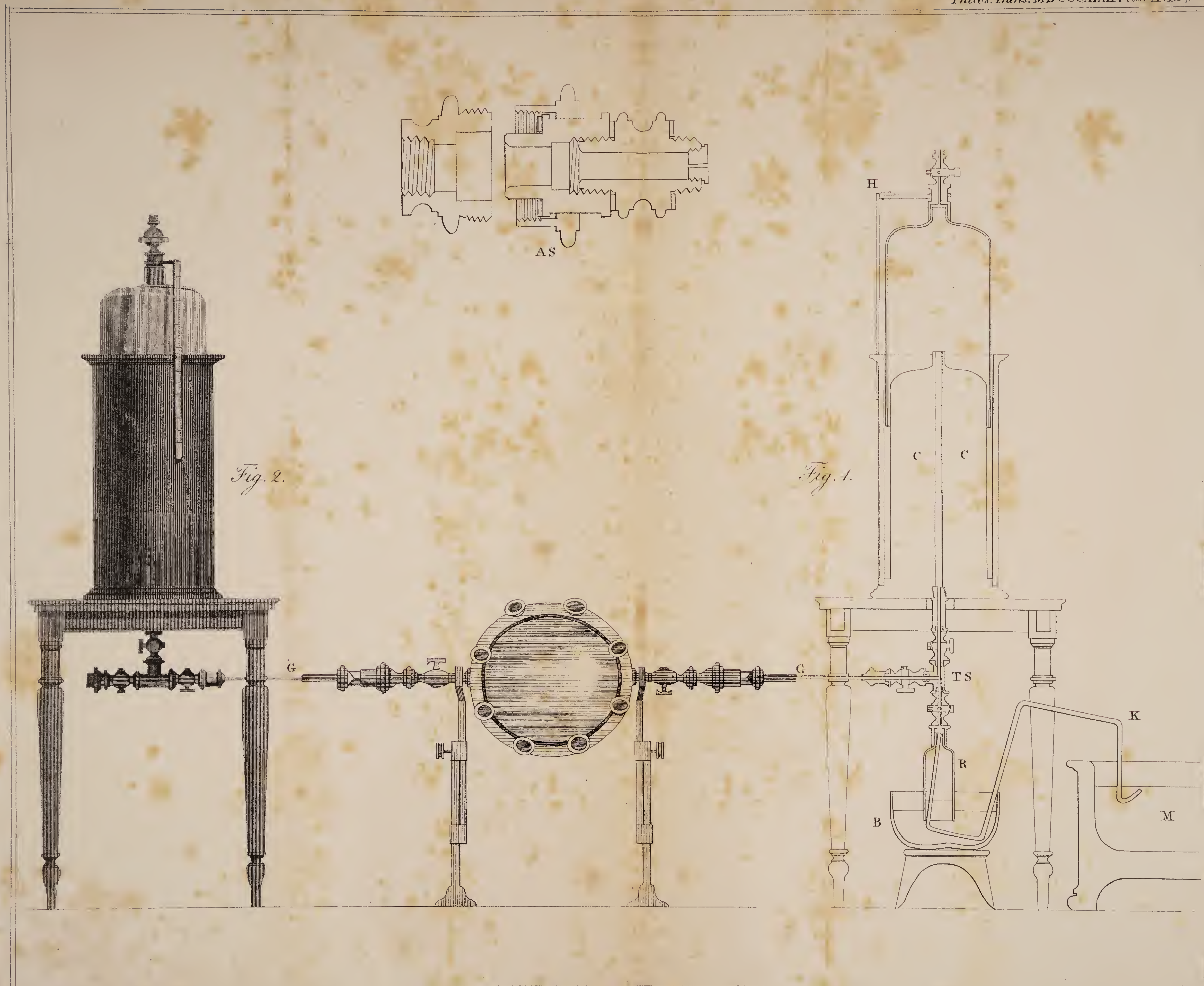
In some cases, when an experiment has been performed with a current of a certain degree of intensity, it is required to repeat it with currents of other degrees of strength, the proportions of which to the first current shall have been accurately determined. The instrument above described readily affords the means of doing this. It may thus be ascertained whether the electro-motive force in any particular combination varies or remains constant when the energy of the current changes.

§ 19. *Process to determine the Degrees of Deviation of the Needle of a Galvanometer corresponding to the Degrees of Force*; *and the Converse.*

When the electro-motive force in the circuit remains constant, the force of the current is simply proportional to the resistance or reduced length of the circuit. If therefore the total resistance of the circuit, when the needle stands at 1°, be determined, and if then, by means of the rheostat and resistance coils, the resistance be successively reduced to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c., the corresponding forces of the current will be 2, 3, 4, 5, &c. Conversely, if the reduced lengths a, b, c, d, &c. necessary to be removed from the circuit in order to advance the needle from each degree to the one next above it be successively ascertained, the forces corresponding to these successive degrees will be

$$\frac{1}{\mathrm{R}},\ \frac{1}{\mathrm{R}-a},\ \frac{1}{\mathrm{R}-(a+b)},\ \frac{1}{\mathrm{R}-(a+b+c)},\ \&c.$$

By the above processes, the relations between the degrees of force and those of the galvanometric scale may be far more readily determined than by either of the ingenious methods of NOBILI, BECQUEREL or MELLONI. When we consider the changes to which the needle of a delicate galvanometer, especially if it be astatic, is subject from the influence of strong currents, the vicinity of magnets, and, in a less degree, from changes of temperature, and in the intensity of the earth's magnetism, the importance of having an easy means of re-graduating the instrument, and of detecting the changes it has undergone, will not be esteemed too lightly.



Silv. Bevan del. Basire Sc.

XIV. *On the Respiration of the Leaves of Plants.*

By William Hasledine Pepys, *Esq.*, *F.R.S.*

Received April 8,—Read May 25, 1843.

After I had written, in conjunction with my friend Mr. Allen, the papers which were published in the Philosophical Transactions for 1808, 1809 and 1829, on the Respiration of Man, the Graminivorous Animals and Birds, showing the deterioration of the atmospheric air by the quantity of carbonic acid gas produced, I instituted a series of experiments on the respiration of plants, and particularly of their leaves. The difficulty of obtaining, for this purpose, specimens which had been previously accustomed to respire constantly under a glass inclosure, and to maintain all their functions in that situation, was overcome by my obtaining possession of a few fine specimens of fig- and vine-trees, which had been under glass culture for a number of years.

To obviate the errors which might arise from making the experiments over water, the apparatus which I formerly used in the combustion of the diamond and other carbonaceous substances was employed, and a modification of the mercurial gasometers, with an appendage consisting of a pair of concave glasses, which formed, when united, an oblate spheroid, was found most useful in the investigation of the nature and chemical composition of the atmospheric air which had served the purpose, first of animal, and then of vegetable respiration.

The pair of concave glasses above mentioned were secured in strong brass rims, well and accurately ground together; and, to prevent their separating when in use, eight brass screws were attached to the rims. There were also three openings in the rims, for the purpose of forming a communication with the gasometers, and with the plant or leaf which was the subject of the experiment.

The mercurial gasometers having been already described and figured in the paper published in the Philosophical Transactions for 1807, it will not be necessary here to repeat their description, but a representation of the oblate spheroid, in which the plant subjected to the experiment was confined, is given, in connexion with the mercurial gasometers, in the annexed Plate XVIII.

The following is the journal of the experiments which I made with this apparatus:—

July 16th, 1838.

From a large mercurial gasometer, connected with the two smaller and the glass hemispheres, I passed 100 cubic inches of respired air, which I suffered to escape by one of the small gasometers after it had been through the hemispheres; I

then admitted fifty-two cubic inches from the large gasometer to one of the small ones; I then passed and repassed the respired air several times through the hemispheres, and on examination found it to contain eight parts in the 100 of carbonic acid.

July 19th.—Barometer 30·220. Thermometer 72°.

I enclosed with great care a fig-leaf between the glass hemispheres, and secured the stem by a grooved split cork, cemented by a strong solution of gum-arabic; I then passed 100 cubic inches of respired air (containing eight parts in the 100 of carbonic acid) through the hemispheres containing the fig-leaf, and let that air escape; I then received into one of the small mercurial gasometers fifty-three cubic inches of the respired air, and passed it through the hemispheres into the other small mercurial gasometer; from thence it was returned, and on examination was found to contain 8 per cent. carbonic acid. I then passed and repassed the respired air over the leaf in the hemispheres, allowing five minutes for each passage. After ten repetitions in this way, I examined the state of the respired air, and found 6 per cent. carbonic acid. I had used in the examination eight cubic inches. The forty-five cubic inches of respired air was now passed and repassed, as before, over the leaf in the hemispheres ten times, five minutes being allowed for each passage. The respired air was then examined, and found to contain 5 per cent. carbonic acid. The respired air was then left in the hemispheres and the two small gasometers until the next morning, at 11 o'clock; on examination it was found to contain 3 per cent. carbonic acid. Many more experiments were made that same year, and with little variation in their results.

July 4th, 1839.—Barometer 30·200. Thermometer 74°.

I repeated the experiment of the 19th of July, 1838, with the same care and attention. On the first examination of the respired air after ten passings and repassings over the fig-leaf in the glass hemispheres (five minutes being allowed for each passage), the respired air containing 8 per cent. carbonic acid at the commencement, I found 6 per cent. carbonic acid, two parts having disappeared.

The process was then continued as before described, and on the second examination I found $4\frac{1}{2}$ per cent. carbonic acid in the respired air. The next morning, the air having been left as before, and the fig-leaf having remained in the hemispheres connected with the two small gasometers, I found on examination, $2\frac{1}{2}$ per cent. carbonic acid.

It may be requisite here to state, that the respired air which was left after the action of the fig-leaf, was also examined by the charged solution of green sulphate of iron and nitrous gas, as to its quantity of oxygen, and gave the usual volume of oxygen for the carbonic acid gas that had disappeared.

The above experiments were repeated with little alteration in their result. The fig-leaves that had been confined in the air were all in as good health as the others on the same tree. A mark had been kept upon them, and I sometimes used the same leaf again.

July 14th, 1840.—Barometer 30·300. Thermometer 59°.

I repeated the experiment of the 19th of July, 1838, and, on the first examination of the respired air, found 6 per cent. carbonic acid, the respired air having contained 8 per cent. at the commencement.

The process was then continued much quicker than before for twenty-five minutes, and on examination of the air, I found 5 per cent. carbonic acid.

On examining the respired air the next day I have generally found it reduced to 2 per cent. carbonic acid.

I repeated the experiment, using a fine healthy vine-leaf in place of the fig-leaf, and secured with the same precaution. I found the vine-leaf not so active an agent as the fig-leaf. The respired air, which at the commencement of the experiment gave 7 per cent. carbonic acid, after two hours, and passing and repassing fifty times, on examination was found to contain 5 per cent. carbonic acid.

A vine-leaf was secured in the glass hemispheres, and the small mercurial gasometers were supplied with atmospheric air, which was passed and re-passed at intervals for two nights and one day. On examining the atmospheric air that had been thus treated, I found that no carbonic acid had been formed, nor was there any alteration in the quantity of oxygen.

A vine-leaf was secured in the glass hemispheres, the mercurial gasometers were connected, and the atmospheric air which they contained was passed and re-passed at intervals. At the end of fourteen days the leaf changed colour in patches of yellow, until, at the conclusion of three weeks from its introduction, it became almost entirely yellow. On examining the atmospheric air, I found that it contained 2 per cent. carbonic acid, and nearly half an ounce measure of fluid had condensed in the hemispheres; the addition of lime water to the fluid produced no turbidness.

During the months of June and July, 1841, I pursued the same train of experiments upon the fig-leaves in the hemispheres of glass, as before described, using respired atmospheric air, and obtained similar results as to the abstraction of the carbonic acid gas and the restoration of the oxygen.

The trees were in good health and ripened their figs as usual.

April 21st, 1842.—Barometer 30·182. Thermometer 62°.

Having secured a fine healthy leaf of the fig-tree in the glass hemispheres conneeted with the mercurial gasometers, I passed 150 cubic inches of respired air, containing 8 per cent. of carbonic acid gas, through the small gasometers and the hemispheres, and then liberated it. I then passed fifty-five cubic inches of the respired air from the large mercurial gasometer into the small one, and from thence through the hemispheres into the other small gasometer, and back again: on examining this air, I found 8 per cent. carbonic acid gas.

I then passed and repassed the air ten times, taking five minutes for each passage, and on examining the air found $6\frac{1}{2}$ per cent. carbonic acid gas. The respired air was

then passed and repassed occasionally for about three hours, when it was examined, and found to contain 4 per cent. carbonic acid.

The hemispheres were then left open to the two small gasometers during the night, and on the morning of the 22nd of April (barometer 30·042, thermometer 61°) the air was examined and found to contain 3 per cent. carbonic acid.

After clearing the gasometer and hemispheres from the remaining respired air, by passing a plentiful quantity of atmospheric air through them, I left seventy-two cubic inches of atmospheric air (containing seventy-nine azote and twenty-one oxygen) until the 25th April (barometer 30·110, thermometer 70°). I then passed and repassed this air several times, and on examination found no alteration in its composition, which, by my eudiometer, was twenty-one parts oxygen and seventy-nine azote; but there was found in the hemispheres about 100 grains of pure water, which must have transpired from the leaf during this confinement.

July 25th, 1842.—Barometer 29·950. Thermometer 71°.

The experiment of the 21st of April last, as to the action of the fig-leaf on the respired air, was repeated, and on leaving, it contained $4\frac{1}{2}$ per cent. carbonic acid, which on examination next morning was reduced to 2 per cent.

It will be seen from the preliminary experiments, that particular attention was paid to preserve the functions of the leaf in a healthy state, both during its inclosure and after its liberation, for in proportion as this essential condition was secured, would be our confidence in the accuracy of the results of the future proceedings for determining the action of the leaf upon a portion of atmospheric air which had served the purpose of respiration.

The conclusions drawn from the numerous experiments made during a long period are, that vegetation, particularly in fine healthy leaves, is always acting to restore the atmospheric air to its original composition of twenty-one parts per cent. of oxygen, by the absorption of the carbonic acid gas and the liberation of oxygen; that this action is accelerated by the aid of light, but that it continues even during the night, although more slowly, and that the production of carbonic acid gas is never observed to take place when the leaf is in health.

The fluid given off during the experiments, when examined, proved to be pure water; when tested by lime water it showed no carbonic acid.

The power possessed by the leaf of taking up carbonic acid gas seems very analogous to that by which food is collected by animals; the first portions of carbonic acid are more quickly taken up than the remaining portions, and one might almost say, that with plants, as with animals, at first a keen appetite is in operation, which being satisfied, is followed by repletion.

INDEX

TO THE

PHILOSOPHICAL TRANSACTIONS

FOR THE YEAR 1843.

A.

B.

C.

E.

F.

G.

T.

V.

W.

LONDON:
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RED LION COURT, FLEET STREET.

METEOROLOGICAL JOURNAL,

KEPT BY THE ASSISTANT SECRETARY,

AT THE APARTMENTS OF THE

ROYAL SOCIETY,

BY ORDER OF

THE PRESIDENT AND COUNCIL.

OBSERVANDA.

Height of the Cistern of the Barometer above the plinth at Waterloo Bridge....83 feet 2 inches.
_____________ above the mean level of the sea ....97 feet.
Height of the receiver of the Rain Gauge above the court of Somerset House ..79 feet.
The External Thermometer is 2 feet higher than the Barometer Cistern.
The Thermometers are graduated to Fahrenheit's scale.
The Barometer is divided into inches and tenths.
The Hours of Observation are of Mean Time, the day beginning at Midnight.
The *daily* observations of the Barometer are *not* corrected.
The *monthly means* are corrected for capillarity and temperature by the Table contained in Mr. Baily's paper in *Phil. Trans.* for 1837.

METEOROLOGICAL JOURNAL FOR JANUARY AND FEBRUARY, 1843.

1843.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M. deg. Fahr.	Diff. of Wet and Dry Bulb Thermometer.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering. Lowest	External Thermometers. Self-registering. Highest	Rain in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
JANUARY															
☉ 1	30.298	30.292	46.7	30.262	30.256	45.5	38	02.1	38.2	38.7	38.5	55.7	.013	NW	Fine—nearly cloudless—light wind throughout the day. Evening, Fine and starlight—sharp frost.
M 2	30.060	30.052	41.3	30.040	30.036	41.6	35	01.9	36.0	37.0	33.6	39.8		W	Fine—light clouds and wind—sharp frost throughout the day. Evening, Fine and starlight—frost.
T 3	30.226	30.220	37.3	30.238	30.230	37.6	30	01.8	30.7	35.8	29.8	38.3		NW	Light fog and wind throughout the day. Evening, Overcast.
W 4	29.888	29.880	39.0	29.960	29.952	40.6	37	01.5	41.3	42.6	30.5	42.2		S	A.M. Overcast—high wind—slight rain. P.M. Fine—light clouds. Evening, Fine and starlight.
T 5	29.836	29.828	38.8	29.866	29.858	40.0	34	02.1	38.8	39.5	35.6	44.3	.152	W	A.M. Fine—light clouds, wind, and rain. P.M. Fine—nearly cloudless. Evening, Fine and starlight.
F 6	30.134	30.126	37.7	30.088	30.080	38.4	32	02.4	36.7	39.8	34.7	42.5		W	A.M. Fine—light clouds and frost. P.M. Cloudy—light wind. Evening, Overcast—slight rain.
S 7	29.946	29.940	40.3	29.802	29.794	41.7	37	01.8	41.8	45.3	37.0	44.9	.030	SSW	Cloudy—lt. wind and fog throughout the day. Ev. Overcast—slight rain.
☉ 8	29.388	29.382	42.6	29.332	29.328	42.8	38	02.0	40.2	39.9	40.3	46.3	.163	SW	A.M. Cloudy—very high wind—slight rain. P.M. Fine—lt. clouds —brisk wind. Evening, Overcast.
M 9	29.684	29.676	38.6	29.602	29.594	39.3	32	02.3	34.5	39.3	32.8	41.4		W	Fine—lt. clouds & wind throughout the day. Ev. Overcast—lt. rain.
T 10	28.892	28.886	41.3	29.052	29.048	41.8	37	01.5	36.8	41.8	34.8	47.0	.133	W	A.M. Cloudy—light wind—high wind, rain, and snow early. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
W 11	29.114	29.106	38.8	29.016	29.010	39.7	33	02.0	34.3	38.8	34.2	43.0		W	A.M. Fine—nearly cloudless—light wind. P.M. Cloudy—light wind. Evening, Overcast—rain and snow.
T 12	28.738	28.734	37.8	28.968	28.960	38.4	31	00.6	32.5	36.0	33.0	39.6	.088	N var.	Overcast—brisk wind throughout the day. Ev. Fine & starlight.
F 13	28.354	28.346	39.0	28.316	28.310	42.0	37	02.0	41.0	42.0	31.2	42.8	.223	S	A.M. Cldy.—very h. wind with rain—very high during night. P.M. Cloudy—high wind—light rain. Evening, Cloudy—high wind.
S 14	29.046	29.040	39.7	28.736	28.730	40.2	31	04.2	36.8	39.5	36.7	45.4		W var.	A.M. Fine—light clouds—brisk wind. P.M. Overcast—lt. rain—high wind. Evening, Overcast—snow—high wind.
☉ 15	28.922	28.916	37.9	28.888	28.882	38.7	32	01.6	34.5	36.0	32.2	41.0	.130	S	A.M. Overcast—light wind. P.M. Fine—light clouds and wind. Evening, Fine and starlight—sharp frost.
● M 16	29.354	29.346	36.4	29.664	29.656	39.3	32	02.5	38.3	40.3	31.0	39.0		W	Fine—light clouds—brisk wind throughout the day. Ev. Cloudy.
T 17	30.214	30.206	38.0	30.216	30.208	39.2	32	02.2	36.8	41.5	35.6	41.7		NW	A.M. Lt. fog & wind. P.M. Fine—lt. clouds. Ev. Overcast—lt. rain.
W 18	30.366	30.358	40.7	30.414	30.406	42.2	38	01.2	43.4	48.0	37.0	44.4	.052	W	Cloudy—light fog and wind throughout the day. Ev. The same.
T 19	30.538	30.530	41.7	30.510	30.502	42.2	36	01.2	36.8	42.7	36.8	49.4		W	Light fog and wind throughout the day. Evening, Overcast.
F 20	30.332	30.326	43.0	30.214	30.208	42.8	37	01.3	38.3	39.3	36.6	44.7		E	Overcast—light wind throughout the day. Evening, The same.
S 21	30.032	30.024	40.9	30.024	30.016	41.6	34	01.0	33.8	38.7	34.2	40.4		E	Ditto ditto. Ditto.
☉ 22	30.060	30.052	41.2	30.020	30.016	42.0	36	01.4	40.8	42.0	34.2	41.8		S	Ditto ditto. Ditto.
M 23	30.062	30.054	42.4	29.976	29.968	44.2	39	01.3	42.7	44.3	41.2	44.0		S	Ditto ditto—slight rain early. Ev. The same.
T 24	29.896	29.890	44.3	29.864	29.856	45.4	41	01.5	45.3	47.0	42.4	47.0	.027	S	A.M. Overcast—high wind—light rain in the night. P.M. Overcast —light rain and wind. Evening, The same.
W 25	30.046	30.040	45.9	30.080	30.072	46.8	41	01.5	42.6	48.7	42.8	48.0		E	Cloudy—light wind throughout the day. Ev. The same.
T 26	30.040	30.032	46.7	30.056	30.048	48.2	44	02.1	47.7	50.8	42.7	49.6		S	Overcast ditto. Ditto.
F 27	29.992	29.984	50.0	29.970	29.962	51.3	48	02.0	50.7	53.3	48.0	52.0		S	Ditto ditto. Ditto.
S 28	29.804	29.796	51.9	29.776	29.768	53.3	50	02.1	54.8	54.8	51.0	56.2		S	A.M. Cloudy—brisk wind. P.M. Fine—nearly cloudless. Evening, Fine and starlight.
☉ 29	29.954	29.946	51.0	29.908	29.902	52.0	48	01.6	49.4	53.5	47.3	57.7		SW	Ovct.—lt. wind—deposition throughout the day. Ev. The same—brisk wind.
◯ M 30	29.768	29.760	51.5	29.794	29.786	52.3	49	02.0	51.3	53.4	49.7	55.3		W	A.M. Overcast—high wind—slight rain early—high wind during the night. P.M. Fine—nearly cloudless. Ev. Fine & starlight.
T 31	29.964	29.956	48.7	29.900	29.896	50.0	44	02.4	45.3	50.8	42.3	49.8		S	A.M. Overcast—light wind. P.M. Cloudy—slight rain. Evening, Overcast—brisk wind.
MEAN.	29.772	29.765	42.3	29.760	29.753	43.3	38	01.8	40.4	43.3	37.7	45.7	Sum. 1.011		Mean Barometer corrected .... 9 A.M. F. 29.740, C. 29.732 .. 3 P.M. F. 29.725, C. 29.717
FEBRUARY															
W 1	29.954	29.948	50.3	29.918	29.910	51.5	46	01.9	47.8	51.0	45.8	51.6	.091	S	Fine—lt. clouds & wind throughout the day—high wind throughout the night. Ev. Fine—high wind.
T 2	29.612	29.604	50.3	29.712	29.704	50.6	48	01.8	50.5	46.3	48.0	53.0		S	Overcast—high wind, with slight rain during the day—high wind at night. Ev. The same.
F 3	29.502	29.498	46.8	29.144	29.136	47.4	41	02.8	40.8	43.8	39.2	51.4	.288	S	A.M. Fine—light clouds and wind. P.M. Cloudy—light rain and wind. Ev. Overcast—hail, snow, rain, and high wind.
S 4	29.342	29.336	38.8	29.570	29.562	40.2	29	00.2	33.6	37.8	35.0	46.6	.166	W	A.M. Cloudy—brisk wind—sharp frost. High wind throughout the night. P.M. Fine—lt. clds.—brisk wind. Ev. Cloudy—brisk wind.
☉ 5	29.838	29.830	38.0	29.806	29.800	38.2	29	00.8	32.7	37.2	32.6	39.0	.055	NW	A.M. Fine—nearly cloudless—sharp frost—h. wind at night. P.M. Fine—lt. clds. Ev. Fine & starlt.—frost.
M 6	29.882	29.874	36.3	29.798	29.792	38.4	31	01.7	35.5	36.7	32.0	37.6		NW	A.M. Fine—lt. clds. & wind—sharp frost. P.M. Ovct.—snow & rain—lt. wind. Ev. Same.
T 7	29.986	29.980	37.0	29.958	29.950	38.0	31	01.2	34.3	35.3	33.6	38.7	.058	N	A.M. Light fog & wind—sharp frost. P.M. Overcast—light snow and wind. Evening, Light rain.
W 8	30.052	30.044	38.0	30.050	30.044	38.7	33	02.5	36.2	38.8	34.2	37.6	.250	E	A.M. Light fog & wind. P.M. Cloudy—brisk wind. Ev. Overcast.
T 9	29.976	29.968	38.8	29.944	29.936	39.6	34	01.0	37.5	39.7	35.8	39.4	.019	N	Ovct.—very slight rain—brisk wind throughout the day. Ev. Same.
F 10	29.884	29.878	39.3	29.828	29.820	40.3	33	02.0	35.3	39.9	35.2	40.2	.100	N	Fine—light clouds & wind throughout the day. Ev. Fine & starlight.
S 11	29.880	29.872	38.7	29.892	29.888	40.0	33	01.0	37.3	41.7	35.3	40.4		N	Overcast—light brisk wind throughout the day. Ev. The same.
☉ 12	30.060	30.052	39.9	30.036	30.030	40.8	34	01.3	37.7	41.2	37.4	42.4		NE	Overcast—very slight rain early—brisk wind throughout the day. Evening, Cloudy.
M 13	30.014	30.006	38.5	29.932	29.924	39.5	33	01.7	35.5	38.3	34.0	42.2		E	Fine—nearly cloudless—light wind—sharp frost throughout the day. Evening, Fine and moonlight—frost.
● T 14	29.718	29.710	35.6	29.610	29.604	37.2	30	01.1	29.8	37.0	28.2	39.6		E	A.M. Light fog & wind—sharp frost. P.M. Overcast—slight rain. Ev. Fine & moonlight—sharp frost.
W 15	29.444	29.436	32.3	29.334	29.328	33.6	24		26.4	28.2	23.8	39.0		N	A.M. Cloudy—lt. wind—sharp frost. P.M. Cloudy—lt. snow. Ev. Cloudy—frosty.
T 16	29.172	29.168	30.6	29.150	29.144	32.0	23	*Frozen*	26.2	32.3	25.8	29.6		N	Cloudy—brisk wind—sharp frost throughout the day. Evening, Moonlight—light clouds—sharp frost.
F 17	29.476	29.470	31.2	29.492	29.486	33.0	24		28.4	35.7	26.4	32.8		NNW	Fine—light clouds and wind—sharp frost throughout the day. Evening, Overcast—snow—sharp frost.
S 18	29.410	29.402	33.4	29.404	29.399	34.2	28	01.1	30.7	33.9	28.6	36.5		NE	A.M. Overcast—snow—sharp frost—high wind. P.M. Overcast——slight thaw. Ev. The same, with high wind.
☉ 19	29.414	29.406	34·7	29.348	29.342	35.4	31	01.4	34.7	35.7	31.5	35.3	.033	ENE	Overcast—high wind during the day. Ev. Overcast—lt. rain & wind.
M 20	29.272	29.266	36.8	29.278	29.272	38.0	34	00.1	37.4	37.8	34.7	38.3	.250	ENE	Overcast—lt. rain—high wind throughout the day. Ev. The same.
T 21	29.396	29.388	39.0	29.394	29.386	41.6	36	01.3	41.7	48.3	37.3	42.6	.175	E	Fine—light clouds and wind throughout the day. Evening, Overcast—light rain and wind.
W 22	29.280	29.272	42.0	29.322	29.316	43.3	39	01.2	43.3	47.8	41.0	49.3	.077	SSE	A.M. Cloudy—light rain and wind. P.M. Cloudy—light wind. Evening, Starlight.
T 23	29.478	29.470	43.8	29.486	29.480	45.7	40	02.0	44.8	46.8	43.5	50.0		SE	Cloudy—light wind throughout the day. Evening, The same.
F 24	29.638	29.632	43.0	29.632	29.624	43.3	37	01.3	38.7	42.8	38.0	49.0		NE	Overcast—lt. wind during the day. Ev. The same, with slight rain.
S 25	29.618	29.610	40.5	29.604	29.598	40.7	35	01.8	37.0	37.5	35.7	43.6		N	A.M. Cloudy—slight rain and wind. P.M. Overcast—light wind. Evening, Overcast—snow and rain.
☉ 26	29.606	29.600	39.0	29.484	29.480	40.0	35	01.2	34.4	37.5	33.8	39.0	.350	N	A.M. Cloudy—slight rain & wind. P.M. Overcast. Evening, Overcast—slight rain.
M 27	28.930	28.924	38.2	28.840	28.834	39.5	35	00.4	36.8	39.4	34.8	38.6	.086	NE	Overcast—slt. rain—brisk wind throughout the day. Ev. The same.
T 28	29.022	29.016	40.0	29.208	29.202	41.0	35	02.0	38.8	41.3	37.2	40.4	.133	NNW	Overcast—slight rain—brisk wind. P.M. Overcast—light wind. Evening, Overcast.
MEAN.	29.602	29.595	39.0	29.578	29.571	40.1	33	01.3	36.6	39.6	34.9	41.6	Sum. 2.131		Mean Barometer corrected .... 9 A.M. F. 29.578, C. 29.570 .. 3 P.M. F. 29.552, C. 29.544

METEOROLOGICAL JOURNAL FOR MARCH AND APRIL, 1843.

1843.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M., deg. Fahr.	Diff. of Wet and Dry Bulb Thermometer.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering. Lowest	External Thermometers. Self-registering. Highest	Rain in Inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
MARCH															
○ W 1	29.698	29.690	40.0	29.758	29.750	41.2	34	02.3	35.8	37.7	34.2	42.2		NNW	A.M. Fine—light clouds and wind. P.M. Cloudy—light snow. Evening, Fine and frosty—starlight.
T 2	29.976	29.968	37.5	29.986	29.978	39.0	31	02.2	33.7	39.3	31.2	39.4		NW	Fine—light clouds, wind, and frost throughout the day. Evening, Fine and frosty—starlight.
F 3	30.092	30.084	37.3	30.096	30.088	38.6	31	01.4	32.3	38.8	31.3	40.2		N	Cloudy—light wind throughout the day. Ev. Fine and starlight.
S 4	30.336	30.328	37.8	30.372	30.364	39.5	32	01.9	35.7	40.8	32.2	40.0		NW	Fine—light clouds & wind throughout the day. Ev. Fine & starlight.
⊙ 5	30.416	30.408	37.6	30.368	30.362	39.0	30	02.1	34.2	41.8	30.5	41.8		N	A.M. Fine—light clouds and wind, with frost. P.M. Lightly overcast. Evening, Overcast.
M 6	30.286	30.278	38.4	30.252	30.246	40.4	32	02.7	39.2	43.2	34.0	43.0		S	Cloudy—light wind throughout the day. Ev. The same, with frost.
T 7	30.218	30.210	38.4	30.192	30.184	40.2	30	02.8	35.7	41.8	32.0	44.0		S	Fine—lt. clouds & wind throughout the day. Ev. Fine & starlight.
W 8	30.292	30.284	38.7	30.326	30.318	40.6	34	02.7	37.7	42.4	33.0	47.8		N	A.M. Fine—nearly cloudless—light wind. P.M. Fine—lt. clouds. Evening, Lightly cloudy.
T 9	30.396	29.390	38.0	30.354	30.346	38.7	31	00.5	34.8	38.2	33.3	43.8		E	Cloudy—lt. wind throughout the day. Evening, Moonlight—lt. clds.
F 10	30.186	30.178	40.0	30.064	30.056	41.4	33	02.7	39.3	42.8	34.8	40.4		SSE	Cloudy—brisk wind throughout the day. Ev. Fine and starlight.
S 11	30.192	30.186	41.2	30.160	30.152	42.8	34	04.2	40.3	44.7	37.6	44.0		S	Cloudy—light wind throughout the day. Evening, The same.
⊙ 12	29.952	29.944	42.7	29.800	29.796	45.0	39	01.9	43.7	48.9	40.0	45.6		S	Overcast—light wind throughout the day. Evening, Cloudy.
M 13	29.744	29.738	44.6	29.686	29.678	47.4	39	03.1	42.7	50.8	39.0	51.0		W	A.M. Fine—light clouds and wind. P.M. Cloudy—light wind. Evening, Overcast—light rain—high wind.
T 14	29.488	29.482	49.0	29.562	29.554	50.0	44	03.4	50.5	54.3	42.7	51.8	.069	W	Cloudy—light wind throughout the day—(high wind throughout the night). Evening, Overcast—very slight rain.
W 15	29.790	29.784	49.5	29.916	29.908	50.3	44	02.0	46.3	50.7	46.3	55.5		N	Overcast—deposition—light wind throughout the day. Evening, Overcast—very slight rain.
● T 16	30.040	30.032	50.0	30.022	30.014	51.2	45	02.2	50.5	52.7	46.2	51.8	.019	SW	Overcast—lt. wind throughout the day. Ev. Moonlight—lt. clouds.
F 17	29.920	29.912	51.0	29.876	29.868	52.6	45	02.2	46.8	57.7	43.6	54.2		S	A.M. Fine—light clouds and wind. P.M. Fine—nearly cloudless. Evening, Moonlight—light clouds.
S 18	29.898	29.892	51.0	29.884	29.878	52.6	45	02.1	45.4	59.8	43.4	59.0		S	A.M. Cloudy—lt. fog & wind. P.M. Fine & cloudless. Ev. Thick fog.
⊙ 19	29.920	29.912	50.0	29.890	29.886	51.0	45	01.2	43.3	45.9	41.3	61.0		NE	Overcast—light wind throughout the day. Evening, Foggy.
M 20	29.588	29.580	49.3	29.594	29.588	52.8	45	02.2	48.3	56.0	42.7	50.8		NE	Cloudy—light wind throughout the day. Ev. The same—brisk wind.
T 21	29.512	29.504	57.0	29.454	29.448	55.4	49	04.6	53.8	56.8	48.0	58.7		E	A.M. Fine—light clouds and wind—high wind throughout the night. P.M. Cloudy—brisk wind. Evening, The same.
W 22	29.440	29.432	55.0	29.462	29.454	56.4	52	03.6	51.8	56.3	50.4	59.0	.163	E	A.M. Cloudy—light wind & rain—high wind with heavy rain early. P.M. Cloudy—light wind. Evening, Overcast—brisk wind.
T 23	29.485	29.478	57.7	29.570	29.562	56.0	51	04.2	54.3	56.3	51.0	59.3		SSE	Cloudy—brisk wind throughout the day. Evening, Fine & starlight.
F 24	29.604	29.596	56.8	29.660	29.652	57.2	51	03.2	53.7	59.7	46.8	57.6		E	A.M. Fine—light clouds & wind—slight rain early. P.M. Cloudy—Light wind. Evening, Fine and starlight.
S 25	29.784	29.776	56.3	29.740	29.732	52.8	44	04.5	47.7	49.3	45.0	60.6		NE	Fine—light clouds, with brisk wind throughout the day. Evening, Fine and starlight—brisk wind.
⊙ 26	29.798	29.790	53.2	29.744	29.738	49.0	37	05.9	45.5	47.5	38.7	53.4		NE	Fine—nearly cloudless—high wind throughout the day. Evening, Fine and starlight.
M 27	29.836	29.828	43.8	29.724	29.716	45.0	35	03.5	40.0	41.3	37.3	51.8		ENE	Cloudy—brisk wind throughout the day. Ev. Overcast—brisk wind.
T 28	29.760	29.752	44.8	29.776	29.768	46.6	38	03.3	43.5	47.3	39.3	44.6		ENE	A.M. Cloudy—light brisk wind. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
W 29	29.966	29.958	46.0	29.984	29.976	45.5	36	04.3	42.3	50.7	33.6	49.0		N	Fine—lt. clouds & wind throughout the day. Ev. Fine & starlight.
○ T 30	29.866	29.858	46.0	29.756	29.748	48.0	39	05.1	48.8	52.8	38.5	52.0		S	Cloudy—light wind throughout the day. Evening, Overcast—light rain—high wind.
F 31	29.480	29.472	51.6	29.398	29.392	52.3	48	04.0	54.8	52.3	48.6	56.2	.036	S	Cloudy—light wind, with occasional light showers throughout the day. Evening, Overcast—light rain.
MEAN.	29.901	29.894	46.1	29.885	29.877	47.0	39	03.0	43.6	48.3	39.6	50.0	Sum. .287		Mean Barometer corrected: 9 A.M. F. 29.858, C. 29.850; 3 P.M. F. 29.839, C. 29.830
APRIL															
S 1	29.540	29.534	51.7	29.518	29.510	54.6	48	02.7	51.3	57.3	49.6	58.0	.102	S	A.M. Overcast—light rain—high wind. P.M. Cloudy—high wind, with showers. Evening, Overcast—high wind.
⊙ 2	29.510	29.504	54.0	29.604	29.600	56.0	50	03.6	54.7	59.5	51.3	59.0	.141	S	A.M. Cloudy—high wind—high wind throughout the night. P.M. Cloudy—high wind—hail and rain. Ev. Fine and starlight.
M 3	29.840	29.832	54.3	29.800	29.794	57.0	50	04.5	56.3	59.3	50.8	60.2	.052	SW var.	Cloudy—light wind throughout the day. Evening, The same.
T 4	29.396	29.390	54.0	29.384	29.378	55.5	50	01.4	51.3	51.3	49.0	61.3	.263	S	A.M. Cloudy—light wind—heavy rain early. P.M. Overcast—light rain and wind. Evening, The same.
W 5	29.764	29.758	61.0	29.840	29.834	54.7	47	04.6	49.8	54.7	43.7	56.3	.283	SW	A.M. Cloudy—brisk wind, hail, and rain—high wind during the night. P.M. Fine—lt. clouds & wind. Ev. Cloudy—high wind.
T 6	29.870	29.862	52.5	29.750	29.744	53.8	47	03.7	51.3	55.4	45.0	57.2	.058	S	A.M. Ovct.—slt. rain—high wind—ditto during night. P.M. Ovct. Ev. The same, with slight rain.
F 7	29.586	29.578	54.9	29.530	29.522	57.0	52	02.7	53.6	60.0	50.2	56.8		S	A.M. Overcast—slight rain & wind—high wind throughout the night. P.M. Cldy. Ev. Same.
S 8	29.612	29.604	64.2	29.596	29.588	57.0	48	05.5	51.0	56.8	47.6	61.7	.450	S	A.M. Fine—lt. clouds—brisk wind. Heavy gale, with heavy rain in the night. P.M. Fine—lt. clds.—brisk wind. Ev. Fine & starlight.
⊙ 9	29.636	29.628	52.7	29.634	29.628	52.0	47	02.5	44.9	46.8	44.8	58.6		NE	Lightly overcast—light wind throughout the day. Ev. The same.
M 10	29.938	29.930	49.7	29.930	29.922	49.4	40	04.2	41.7	43.0	36.4	48.3		NW	A.M. Fine—light clouds and wind. P.M. Cloudy—light snow—rain and wind. Ev. Fine and starlight—sharp frost.
T 11	30.010	30.002	49.6	30.000	29.992	47.7	32	04.2	39.5	44.6	35.2	48.0	.055	WNW	Fine—light clouds and wind throughout the day. Evening, Fine and moonlight—light frost.
W 12	29.970	29.962	49.3	29.914	29.906	46.3	35	03.6	39.3	43.7	33.0	45.7		NW	A.M. Fine—lt. clouds & wind. P.M. Cloudy—lt. wind. Ev. Moonlight—light clouds.
T 13	29.830	29.822	46.2	29.890	29.882	45.6	34	03.0	38.3	41.5	35.0	45.0	.066	NW	A.M. Fine—lt. clds. & wind—snow during the night. P.M. Cloudy—slight snow. Ev. Light rain.
● F 14	29.914	29.906	45.0	29.904	29.896	46.3	35	04.5	44.3	52.2	34.0	46.0		W	Cloudy—brisk wind throughout the day, with occasional slight rain. Evening, Light fog.
S 15	30.138	30.130	47.3	30.120	30.112	49.6	43	03.1	51.0	55.7	44.0	53.3		W	A.M. Light fog & wind. P.M. Cloudy—light wind. Ev. The same.
⊙ 16	29.968	29.960	55.6	29.858	29.852	53.5	45	05.3	54.0	58.6	49.2	57.6		E	Fine—light clouds and wind throughout the day. Ev. Overcast.
M 17	29.964	29.956	58.0	29.956	29.948	55.7	48	04.0	52.0	62.3	45.7	60.3		N	Ditto ditto. Ev. Fine and starlight.
T 18	30.150	30.144	56.0	30.098	30.090	55.2	42	05.5	52.7	60.7	45.8	64.0		NE	Ditto ditto. Ditto.
W 19	29.992	29.984	51.6	29.876	29.868	54.2	45	01.8	45.7	58.8	41.8	62.2		E	A.M. Light fog and wind. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
T 20	29.736	29.728	57.7	29.744	29.740	57.0	49	05.2	57.3	65.0	45.8	60.4		S	Fine—light clouds & wind throughout the day. Ev. Fine & starlight.
F 21	29.902	29.896	58.2	29.888	29.880	58.7	51	04.0	55.7	61.7	49.3	67.3		W	Ditto ditto. Ev. Cloudy—light rain.
S 22	29.876	29.868	56.7	29.954	29.946	58.2	52	04.0	54.3	54.5	51.0	65.6	.050	SSW	A.M. Cloudy—hail, rain, and wind. P.M. Cloudy—light clouds and wind. Evening, Fine and starlight.
⊙ 23	30.104	30.096	58.5	30.068	30.060	56.7	39	05.7	50.3	57.3	42.3	63.7	.041	S	A.M. Cloudy—light wind. P.M. Fine—light clouds and wind. Evening, Fine and starlight.
M 24	30.060	30.052	60.7	30.022	30.014	55.7	45	04.6	50.7	55.7	42.3	58.6		E	A.M. Fine—light clouds & wind. P.M. Cloudy—slight shower. Evening, Fine & starlight.
T 25	29.774	29.766	50.9	29.580	29.572	52.2	44	03.5	47.7	52.5	42.0	57.0		SSE	A.M. Ovct.—lt. wind, with occasional showers. P.M. Cloudy—hail, rain & wind. Ev. Fine & starlight.
W 26	29.670	29.662	49.0	29.700	29.692	51.4	41	02.4	41.3	52.7	38.7	55.0	.313	W	A.M. Overcast—light rain, hail, and wind. P.M. Cloudy—light wind. Evening, Overcast.
T 27	29.856	29.848	52.9	29.898	29.890	51.5	41	03.8	45.0	52.5	40.6	54.0	.080	NW	Overcast—light wind throughout the day. Ev. Fine and starlight.
F 28	29.800	29.794	50.9	29.698	29.690	51.8	43	04.3	49.3	51.4	43.2	54.6		E	A.M. Cloudy—lt. wind. P.M. Overcast—lt. rain & wind. Ev. Same.
○ S 29	29.712	29.704	51.2	29.704	29.698	53.0	40	04.6	49.8	55.3	45.4	54.6	.033	W	A.M. Overcast—light wind. P.M. Cloudy—light wind. Evening, Fine and starlight.
⊙ 30	29.866	29.860	69.0	29.934	29.928	57.2	51	06.1	58.8	62.5	48.0	66.0		NE	Fine—lt. clouds—lt. brisk wind throughout the day. Ev. Fine & starlt.
MEAN.	29.833	29.825	54.1	29.813	29.806	53.5	44	03.9	49.4	54.8	44.0	57.9	Sum. 1.987		Mean Barometer corrected: 9 A.M. F. 29.769, C. 29.760; 3 P.M. F. 29.751, C. 29.743

1843.	9 o'clock, A.M. Barometer uncorrected. Flint Glass.	9 o'clock, A.M. Barometer uncorrected. Crown Glass.	9 o'clock, A.M. Att. Ther.	3 o'clock, P.M. Barometer uncorrected. Flint Glass.	3 o'clock, P.M. Barometer uncorrected. Crown Glass.	3 o'clock, P.M. Att. Ther.	Dew Point at 9 A.M., deg. Fahr.	Diff. of Wet and Dry Bulb Ther.	External Thermometers. Fahrenheit. 9 A.M.	External Thermometers. Fahrenheit. 3 P.M.	External Thermometers. Self-registering. Lowest	External Thermometers. Self-registering. Highest	Rain in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
M 1	30.130	30.124	72.3	30.146	30.138	59.8	49	07.3	59.8	65.8	52.3	65.0		E	A.M. Fine—ligbt clouds—brisk wind. P.M. Fine and cloudless—brisk wind. Evening, Fine aud starligbt.
T 2	30.186	30.180	70.9	30.090	30.082	60.0	51	07.2	59.0	63.3	49.0	67.7		E	A.M. Fine—light clouds and wind. P.M. Flne and cloudless—brisk wind. Evening, Fine and starlight.
W 3	29.942	29.934	53.6	29.856	29.848	56.7	45	02.3	46.0	60.7	43.7	67.2		E	A.M. Overcast—ligbt wind. P.M. Fine and cloudless. Ev. Gloudy.
T 4	29.808	29.800	61.3	29.748	29.740	59.5	50	05.6	58.7	62.6	46.3	62.3	.022	S	A.M. Fine—light clouds and wind—rain early. P.M. Cloudy—ligbt wind. Evening, Fine and starlight. [with rain.
F 5	29.720	29.712	58.0	29.708	29.700	59.7	52	04.5	56.2	59.8	50.4	64.8	.158	S	Cloudy—brisk wind throughout the day—rain early. Ev. The like,
S 6	29.392	29.384	56.5	29.562	29.556	55.3	51	00.6	47.4	45.8	48.2	62.2	1.133	NNW	Overcast—light rain—brisk wind tbroughout the day—very heavy rain in the night. Evening, Fine and starlight.
☉ 7	29.676	29.668	70.3	29.616	29.610	57.0	45	05.1	52.3	54.0	40.3	70.6	.300	S	Fine—lt. clouds & wind througbout tbe day. Ev. Overcast—llght showers.
M 8	29.596	29.590	51.4	29.580	29.572	51.8	45	01.8	45.5	46.4	42.3	60.6	.036	NNE	Overcast—light rain and wind throughout the day. Ev. The same.
T 9	29.642	29.636	50.3	29.756	29.748	52.8	45	01.6	47.2	52.7	44.2	49.5	.463	N	Overcast—lt. wind tbroughout tbe day—rain early. Ev. The same.
W 10	30.044	30.036	54.8	30.110	30.102	53.2	46	02.8	50.7	53.7	46.2	54.7		N	Overcast—light wind throughout the day. Ev. Fine and moonlight.
T 11	30.234	30.226	51.0	30.214	30.206	53.3	45	02.6	49.2	57.4	43.8	56.4		N	Overcast—ligbt wind tbroughout the day. Evening, Cloudy.
F 12	30.202	30.196	61.3	30.016	30.008	58.0	47	05.4	56.7	62.6	46.3	64.6		S	A.M. Fine—light clouds and wind. P.M. Cloudy—ligbt wind. Evening, Overcast—slight rain.
☽ S 13	29.948	29.940	56.3	29.940	29.934	58.8	51	05.1	56.2	63.2	52.6	66.2	.033	S	A.M. Cloudy—light wind. P.M. Fine—light clouds and wind, Evening, Moonlight—light clouds.
☉ 14	29.848	29.840	58.0	29.712	29.708	60.0	50	05.1	56.7	60.4	48.8	64.4		S	A.M. Cloudy—lt. wind. P.M. Overcast—lt. wind. Ev. Overcast—light steady rain. [The same.
MAY M 15	29.544	29.538	58.0	29.570	29.562	59.7	53	04.2	55.2	58.7	51.0	69.0	.219	S	Cloudy—light wind witb gentle showers throughout the day. Ev.
T 16	29.432	29.424	57.7	29.458	29.450	58.8	51	03.9	54.8	57.8	50.7	63.5	.100	E	Cloudy—light wind, with very sligbt showers throughout the day. Evening, The same.
W 17	29.518	29.510	56.2	29.594	29.588	58.5	52	02.2	52.2	55.7	51.2	59.3	.063	W	A.M. Overcast—light rain and wind. P.M. Cloudy—light wind. Evening, Overcast—slight rain.
T 18	29.850	29.842	53.2	29.888	29.880	54.2	46	02.7	47.7	49.3	45.3	58.6	.283	N	Overcast—brisk wind, with occasional slight showers throughout the day. Evening, The same.
F 19	29.928	29.920	52.3	29.932	29.924	54.9	48	02.9	48.3	53.8	46.3	52.0	.080	E	Cloudy—lt. wind tbroughout the day—slight rain early. Ev. Cloudy.
S 20	29.884	29.876	58.0	29.836	29.828	56.3	48	05.5	55.0	54.8	49.0	56.3		E	A.M. Cloudy—light brisk wind. P.M. Fine—light clouds & wind. Evening, Overcast—slight rain.
☉ 21	29.696	29.690	60.4	29.658	29.652	58.5	52	03.5	56.3	60.5	50.8	59.3	.302	S	A.M. Cloudy—light wind—heavy rain in the night. P.M. Overcast. Evening, The same, with ligbt rain.
M 22	29.718	29.710	65.4	29 694	29.688	58.7	51	04.9	56.8	57.3	47.8	65.3	.063	SSE	Ovct.—lt. wind, witb gentle showers throughout the day. Ev. Same.
T 23	29.750	29.744	57.3	29.718	29.710	58.8	52	05.3	57.5	57.3	51.6	62.2	.086	SSE	Cloudy—light wind, witb sbowers throughout the day. Evening, Overcast—ligbt rain—heavy tbunder and lightning.
W 24	29.532	29.524	56.9	29.578	29.570	60.6	54	01.8	54.2	61.8	53.8	62.6	.380	E	A.M. Overcast—light wind—heavy rain early. P.M. Cloudy—brisk wind. Evening, Fine and starlight.
T 25	29.676	29.668	70.0	29.678	29.670	62.0	53	06.3	59.8	64.3	51.0	73.4		S	A.M. Dark heavy clouds—light wind. P.M. Fine—light clouds and wind. Ev. Fine and starlight. [Tbe same.
F 26	29.754	29.748	67.0	29.668	29.660	61.6	55	06.6	60.2	56.3	50.6	68.2		S	A.M. Fine—lt. clouds & wind. P.M. Overcast—slight showers. Ev.
S 27	29.570	29.562	60.4	29.484	29.478	61.3	55	06.2	59.8	58.3	50.3	65.7	.036	SE	A.M. Cloudy—brisk wind witb showers. P.M. Dark beavy clouds, witb showers. Evening, Fine and starlight.
☉ 28	29.560	29.552	62.0	29.624	29.620	60.0	52	05.8	56.7	55.5	47.8	63.0	.150	S	A.M. Cloudy—light wind—slight rain. P.M. Overcast—lt. rain. ¼ hefore 3, loud thunder—heavy rain. Ev. Overcast—rain.
● M 29	29.966	29.958	55.6	29.994	29.986	55.0	46	03.9	48.2	48.3	48.2	62.2	.211	E	Overcast—light wind, with occasional sbowers throughout the day. Evening, Ligbt fog. [—sligbt rain.
T 30	30.144	30.138	58.7	30.088	30.080	57.6	49	05.8	54.3	60.0	42.3	61.7	.175	E	A.M. Fine—lt. clouds & wind. P.M. Cloudy—lt. wind. Ev. Ovct.
W 31	29.906	29.900	56.8	29.886	29.880	59.2	54	03.7	59.3	65.0	51.7	64.6	.016	SW var.	Overcast—light brisk wind, with very gentle sbowers throughout tbe day. Evening, The same.
MEAN	29.800	29.793	59.1	29.787	29.780	57.8	50	04.3	54.1	57.5	48.2	64.3	Sum. 4.309		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.723 .. 29.713 C. 29.715 .. 29.705
T 1	29.716	29.708	59.7	29.652	29.646	62.0	56	04.9	61.3	65.3	56.3	67.6	.086	S	Cloudy—light wind througbout the day—rain early. Ev. Overcast.
F 2	29.336	29.328	60.6	29.342	29.336	63.7	58	01.8	57.3	64.2	56.0	67.3	.041	E	A.M. Overcast—brisk wind, with occssional showers. P.M. Cldy. with showers. Evening, Cloudy. [light.
S 3	29.486	29.480	60.4	29.516	29.508	62.8	55	05.9	59.2	64.2	53.8	66.3	.061	S	Dark heavy clouds—hrisk wind throughout the day. Ev. Fine & star-
☉ 4	29.700	29.694	72.3	29.694	29.688	64.0	56	06.7	62.5	63.7	52.2	69.3		E	A.M. Dark heavy clouds—light wind. P.M. Fine—light clouds—heavy sbowers. Evening, Fine and starligbt.
M 5	29.850	29.844	72.0	29.838	29.830	62.6	52	06.9	57.3	58.2	48.5	71.3	.033	S	A.M. Fine—light clouds and wind, with gentle showers. P.M. Cloudy—brisk wind. Evening, Fine and starlight.
T 6	29.840	29.832	66.4	29.852	29.844	60.3	48	06.3	56.2	55.2	48.4	79.0	.130	SE	A.M. Cloudy—light breeze—beavy rain. P.M. Overcast—sligbt showers. Ev. Overcast. [Ovct.—lt. rain—high wind.
W 7	29.950	29.942	69.0	29 878	29.870	60.7	52	06.0	56.7	57.8	47.6	66.3	.247	S	A.M. Cloudy—brisk wind. P.M. Ovct.—stiff breeze—lt. rain. Ev.
T 8	29.454	29.450	65.2	29.412	29.404	61.2	54	05.9	58.7	61.0	51.7	61.2	.130	S var.	Fine—ligbt clouds—high wind throughout the day. Ev. Overcast—slight rain—very high wind.
F 9	29.422	29.416	64.0	29.532	29.524	61.8	54	06.2	60.3	61.8	53.0	67.7	.033	S	A.M. Cloudy—high wind—bigh wind throughout the night. P.M. Fine—light clouds—high wind. Evening, Cloudy.
S 10	29.816	29.808	61.0	29.900	29.894	61.2	53	06.2	58.8	57.8	51.8	65.3	.055	W	A.M. Cloudy—light breeze. P.M. Overcast—light breeze, with showers. Evening, Cloudy. [Cloudy—slight rain.
☉ 11	30.108	30.100	62.7	30.098	30.090	61.7	50	04.4	55.3	58.8	50.0	66.8	.047	W	A.M. Overcast—light breeze. P.M. Fine—lt. clouds & breeze. Ev.
○ M 12	30.054	30.046	58.2	30.014	30.006	59.8	52	04.4	54.3	56.7	50.5	61.4		N	Cloudy—light breeze throughout tbe day, with slight rain. Ev. The same.
T 13	29.878	29.870	56.3	29.840	29.832	57.0	51	01.0	49.7	53.7	49.5	58.8	.211	NNW	Overcast—ligbt rain—stiff breeze throughout the day. Ev. The same.
JUNE W 14	29.970	29.962	57.6	30.000	29.992	60.0	54	02.6	58.7	63.8	50.5	60.0	.119	N	Overcast—slight rain and wind throughout the day. Ev. The same.
T 15	30.036	30.030	62.0	30.022	30.014	62.3	59	04.3	63.3	66.8	58.2	65.4	.016	NE	A.M. Cloudy—slight rain and wind. P.M. Fine—ligbt clouds and wind. Evening, Cloudy—few stars.
F 16	30.000	29.994	74.8	29.984	29.976	64.4	58	06.0	63.7	68.4	53.6	72.6		N	Fine—light clouds and breeze throughout the day. Evening, Fine and moonlight.
S 17	30.058	30.050	60.8	30.024	30.016	63.4	54	03.2	55.3	69.8	50.4	69.8		N	A.M. Cloudy—light breeze. P.M. Fine—light clouds and breeze. Evening, Fine and starlight. [Ev. Few stars.
☉ 18	29.986	29.978	60.4	29.904	29.898	64.0	56	02.1	54.8	67.8	52.0	71.2		NE	A.M. Fine—lt. clouds and breeze. P.M. Cloudy—lt. rain & wind.
M 19	29.878	29.870	59.9	29.902	29.894	62.5	55	02.4	53.5	59.8	51.0	70.0		N	Lightly overcast—stiff breeze tbroughout the day. Ev. The same.
T 20	30.122	30.114	57.7	30.176	30.168	59.0	48	03.3	51.7	55.7	51.0	63.2		N	Overcast—stiff breeze throughout the day. Ev. The same.
W 21	30.178	30.170	70.2	30.086	30.078	61.7	58	07.6	59.3	68.7	50.0	62.0		W	Fine—light clouds & breeze throughout the day. Evening, Cloudy—light breeze.
T 22	30.044	30.036	61.5	30.042	30.036	64.0	55	06.3	60.8	66.7	56.6	72.6		N	Cloudy—lt. breeze throughout the day. Ev. Lightly cloudy—few stars.
F 23	30.126	30.118	70.7	30.082	30.074	64.6	55	07.3	61.3	68.7	51.3	72.8		N	Fine—lt. clouds and breeze throughout tbe day. Ev. Fine & starlight.
S 24	30 070	30.064	64.7	30.036	30.028	64.9	55	06.5	59.3	63.7	54.0	70.3		N	Fine—light clouds and breeze throughout tbe day. Ev. Overcast.
☉ 25	29.986	29.978	59.0	29.934	29.928	62.0	52	04.0	52.5	61.4	51.0	65.4		NNW	A.M. Lightly overcast—light breeze. P.M. Heavy clouds—ligbt breeze. Evening, Fine and starlight.
M 26	29.940	29.932	60.2	29.906	29.898	61.6	52	04.5	56.4	66.7	49.3	64.0		N	Cloudy—light breeze throughout the day. Ev. Fine and starlight.
● T 27	29.830	29.824	72.2	29.736	29 728	65.2	53	08.3	64.3	70.0	53.7	79.7		E	Fine—light clouds and breeze throughout the day. Ev. Overcast.
W 28	29.674	29.666	62.8	29.682	29.676	62.3	45	04.8	54.3	57.2	51.5	73.6		N	A.M. Cloudy—light breeze. P.M. Fine—light clouds and breeze. Evening, Cloudy—slight shower.
T 29	29.810	29.802	64.5	29.816	29.808	61.8	42	05.7	56.6	61.8	47 3	63.3	.016	NW	A.M. Cloudy—light breeze. P.M. Dark heavy clouds—lt. breeze. Evening, Cloudy—few stars.
F 30	29.922	29.914	65.5	29.928	29.920	62.3	54	07.3	60.3	61.2	55.2	64.3		W	Cloudy—light breeze tbroughout the day. Ev. Cloudy—few stars.
MEAN.	29.875	29.867	63.7	29.861	29.853	62.2	53	05.1	57.8	62.6	51.9	67.6	Sum. 1.225		Mean Barometer corrected .... 9 A.M. 3 P.M. F. 29.785 .. 29.775 C. 29.776 .. 29.766